Big Hole River Approximate Level Floodplain Study, Phase 2 - Hydraulic Analysis and Mapping

Topographic Data Assessment

MT DNRC

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Plan Design Enable

Big Hole River

Topographic Assessment

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I hereby certify that all work products (maps, reports, etc.) prepared for this project were done so under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Montana.

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1. Introduction

According to the Montana Department of Natural Resources and Conservation (DNRC), approximately three-quarters of the regulatory floodplains mapped within the state of Montana are “Approximate” (Zone A) as opposed to “Detailed” (Zone AE). There are many possibilities for the disparity in floodplain studies such as expense and failure of previous studies to meet present standards. Many of Montana’s floodplain studies were produced in the 1970s and 1980s during the initial stages of the National Flood Insurance Act, with little emphasis placed on rural areas or those with little development. Additionally, the datasets and methods employed to create the Zone A areas were crude and frequently lacked the necessary documentation.

As with much of the western United States, Montana has experienced a large degree of development in many of its communities. This has led to the development of areas within and around flood prone areas previously unmapped or designated as Zone A. As previously stated, the development of much of the effective Approximate areas was created using data presently considered crude and frequently lacked the documentation necessary for regulation. This has resulted in the respective communities unable to properly regulate the floodplains without producing a detailed study. However, detailed studies can be too expensive for some developing areas as they require highly detailed topographic sources. In order to assist areas in need of more accurate floodplain delineations, the DNRC has decided to research cheaper techniques using “modernized” data sets and “enhanced” techniques for performing Approximate level studies that will offer an efficient and more economical product for regulation of flood prone areas in rural and developing communities in Montana. The enhanced techniques, which include employment of rapid floodplain mapping software, allow for a more efficient workflow. However, the mapping is only as accurate as the topographic source being utilized. For detailed studies, the purchase of detailed topography data can cost up to 50% of the total study. For many communities, the expense of such a data source is a deterrent for performing a detailed analysis. Typically, communities are reliant upon the utilization of 10- and 30-m digital elevation models (DEM) as a topographic source. This is largely due to the fact that the 10- and 30-m DEMs have been accepted by FEMA for Approximate studies and are typically the best available data as they are readily available and free for all locations within the United States. As detailed by Anderson Consulting Engineers in 2010 (**Reference 5**), the employment of 10-m DEMs for Approximate floodplain studies revealed significant horizontal and vertical errors. Therefore, it is necessary to research additional data sources that are available.

The overall goal of this project is to develop accurate floodplain maps for the entire Big Hole River in southwest Montana. This report summarizes the first two components of the overall flood study: 1) a hydraulic structure inventory and 2) a topographic data source assessment. The hydraulic structure inventory identifies stream crossing locations along the entire study reach, the type of hydraulic structure including pertinent dimensions for modeling purposes, and the likelihood of each structure to impose backwater during the base (1% annual-chance or 100-year) flood. The primary goal of the topographic assessment task is to investigate new and existing topographic data sources for the Big Hole River and perform the necessary comparisons to determine the most accurate terrain not only for the present study but for Approximate level hydraulic analyses. The 5-m IFSAR DEM utilized in the analysis is relatively new and has never been used before in Montana or FEMA Region VIII, although it is being utilized in other states and FEMA Regions. Given that the 5-m DEM is not a free product, the DNRC wanted to determine whether it is worth employing for future Approximate studies. Each topographic source was utilized to model three separate reaches along the Big Hole River. The results of each simulation were then compared with the results of a model created from survey data. The results measure the accuracy of the various topographic datasets when utilized in the creation of Zone A areas.

2. Purpose of Investigation

The purpose of the present study is twofold:

1. Perform hydraulic structure inventory and assessment. The purpose of this subtask is to identify the hydraulic structures located in the channel or floodplain and provide a description of the hydraulic characteristics along with an assessment of each structure's potential to impose backwater conditions during the base flood. In the event that LiDAR surface topography is collected, this information may be used to enhance the Big Hole River flood study.
2. Perform topographic data options assessment. The purpose of this subtask is to evaluate all topographic data sources available within the Big Hole River watershed and assess their accuracy when utilized for Zone A hydraulic modeling and floodplain mapping. The accuracy of each topographic source shall be measured by comparing the results of the respective hydraulic models against survey results which are considered to be the most accurate data available. The results of this study shall assist the DNRC and communities of Montana in the selection of an appropriate topographic source in order to provide a more accurate and cost efficient product for floodplain regulation.

The topographic sources utilized for the study are as follows:

1. Survey data collected for this project between the dates of 6/22/2012 – 7/11/2012
2. 5-m DEM supplied by Intermap Technologies Corp.
3. 10-m DEM supplied by the United States Geological Survey (USGS)
4. 30-m DEM supplied by the USGS
5. 30-m DEM collected by the 2000 Shuttle Radar Topographic Mission (SRTM)

3. Methodology

3.1. Hydraulic Structure Inventory Assessment

Locations of hydraulic structures were first identified by inspection of aerial imagery and a Structure ID was assigned beginning downstream and progressing upstream. A total of 48 structures were identified and locations are shown on **Figure 1**. Much coordination was done with private landowners, project stakeholders, and Atkins to visit each structure; however some structures were not visited due to a lack of landowner permission and access. Atkins performed field reconnaissance of the structures June 19 – 20, 2012 beginning at the upper watershed and working downstream. Each structure visited was attributed with information relevant to a flood study including: type, culvert or bridge dimensions, material, abutment type, entrance type, pier configuration and size, condition, backwater potential, and other hydraulic notes. Tape measures were used for performing relative measurements. For bridges, the span length was measured between abutments; the deck width was measured perpendicular to traffic; deck thickness and guardrail heights were measured relative to the deck surface; and piers were measured from the channel where practical. For culverts, culvert height and width were measured in horizontal and vertical planes; the inlet to deck and deck to outlet distances were measured relative to the deck; and culvert length was measured parallel to the culvert from inlet to outlet. In some cases, bridge configurations were not constant and multiple values exist in one field. For this reason, some fields were defined as STRING type to contain multiple values. In other cases, additional dimensions were placed in the Notes field. In addition to dimensions, photographs of each structure were taken showing, at a minimum: downstream view of channel, downstream face of structure, upstream view of channel, and upstream face of structure. The resultant table detailing the performed inventory as well as photos of each structure is located in **Appendix A**.

For all inspected structures, the backwater potential of flood flows (i.e. 1-percent-annual-chance event) was qualitatively assessed. The backwater potential was rated on a ‘Low’ to ‘High’ scale with ‘Low’ representing little backwater potential and a ‘High’ rating representing an undersized culvert or bridge with embankments blocking the majority of the floodplain. All structures located upstream of Wisdom were assigned a ‘Low’ rating as they were typically multiple barreled culverts or perched bridges with road grades approximately equal to the floodplain. Hence, it was assumed that floodwaters would easily pass the structure without much headloss. All other structures except 19 – 21 were given a ‘Low’ to ‘Medium’ rating as it was discovered the structures spanned the majority of the expected floodplain or flood flows were expected to easily pass the structure without a significant increase in the water surface elevation. Structures 19 – 21 were designated as ‘High’ due to the respective bridges only spanning the channel coupled with high embankments found in the floodplains. As seen in **Figure 2**, these bridges are located along MT Hwy 43 from the Town of Wise River to Wisdom. During rare flow events, it is expected that Structures 19 – 21 will exhibit a significant increase in the water surface profile largely produced by the encroachment of the elevated road grade present within the floodplains.

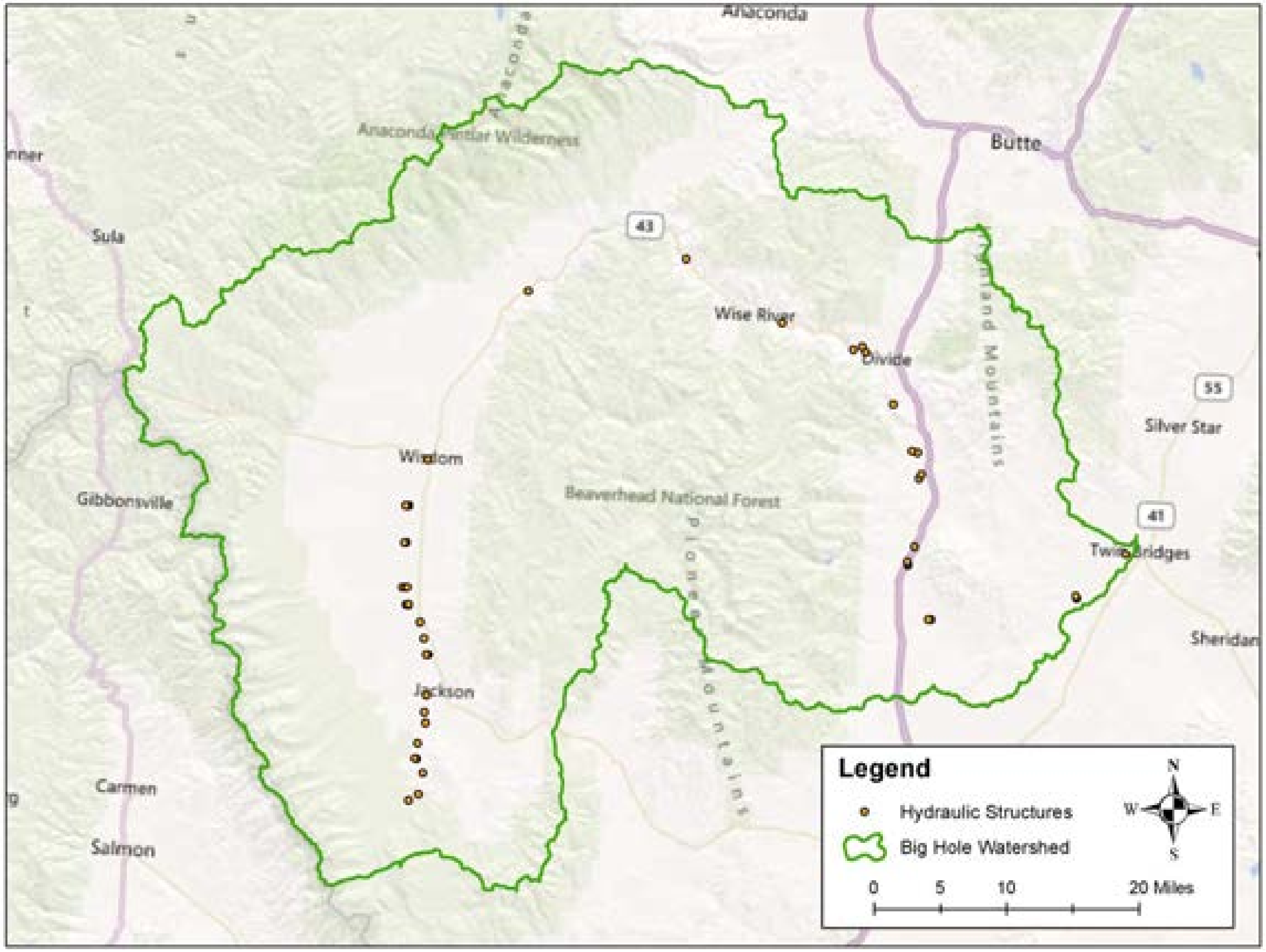

Figure 1. Location of hydraulic structures within the Big Hole River watershed

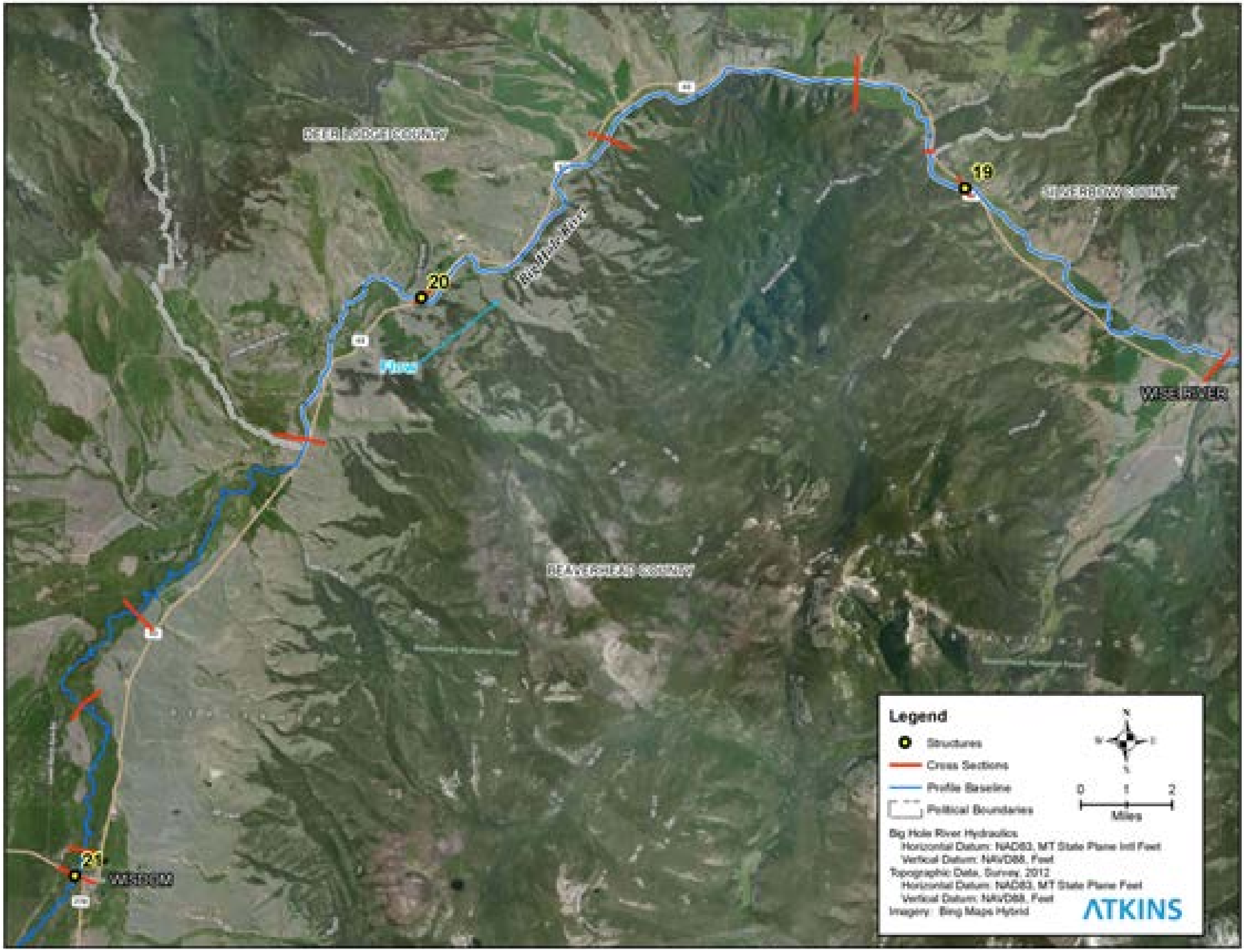

Figure 2. Location of hydraulic structures 19, 20, and 21

3.2. Topographic Data Options Assessment

As previously mentioned, four (4) topographic data sources were assessed for utilization within an Approximate hydraulic analysis and resultant floodplain mapping. The analyzed topographic datasets consists of a 5-m DEM supplied by Intermap Technologies Corp., 10-m DEM supplied by the USGS, 30-m DEM supplied by the USGS, and 30-m DEM collected by the 2000 Shuttle Radar Topographic Mission (SRTM).

The 5-m data supplied by Intermap Technologies Corp. was purchased by the MT DNRC in 2012. The data for the hydro-enforced DEM was collected between the dates of July 16 – September 26, 2008 by Interferometric synthetic aperture radar (IFSAR). The DNRC purchased the 160.4 mi^2 area for the Big Hole River Hydraulic study at a rate of approximately \$39/mi^2. **Figure 3** displays the area encompassed by the purchased IFSAR dataset.

The 10- and 30-m DEMs provided by the USGS are bare-earth models and were downloaded from the USGS data server in June of 2012 at no cost. According to the USGS (**Reference 16**), the data for the 10- and 30-m DEMs was collected between the years of 1923 – 1959. These datasets were derived from cartographic contour information displayed on the respective quadrangle maps and were developed using complex linear interpolation from contours. According to the USGS, "the accuracy of the National Elevation Dataset (NED) varies spatially because of the variable quality of the source digital elevation models (DEMs). As such, the NED inherits the accuracy of the source DEMs. The most recently published figure of overall absolute vertical accuracy expressed as the root mean square error (RMSE) is 2.44 meters. Details of this analysis are explained in the Vertical Accuracy of the National Elevation Dataset paper, and are published in the "*Digital Elevation Model Technologies and Applications: The DEM Users Manual 2nd Edition"* (**Reference 3)**.

The 30-m SRTM data was collected by a modified radar system that flew onboard the Space Shuttle Endeavor in February 2000, using IFSAR. Unlike the aforementioned 10- and 30-m datasets that were created from bare-earth, the SRTM data was created from first returns. This results in the vegetation being realized within the dataset. According to the USGS the SRTM data has a vertical accuracy of 10-m RMSE.

In order to perform the hydraulic assessment, the US Army Corps of Engineers hydraulic model titled HEC-RAS (Version 4.1.0) was utilized. For each analyzed reach, a separate model was developed for each dataset with the subsequent results compared to the results of a similar model consisting only of surveyed topographic data. The accuracy of each source was measured by comparing the respective results with those of survey data, which was considered to be the most accurate model. The methodology of the hydraulic assessment of the topographic data is further detailed below.

To properly gauge the accuracy of the aforementioned topographic sources for utilization in Approximate floodplain studies, three assessment reaches along the Big Hole River were selected for review. The three selected reaches of the study exhibit different hydraulic features that provide a wide range of scenarios that can be present when performing a hydraulic analysis. The three modeled reaches of the Big Hole River are listed below in **Table 1**. Discharge values presented in **Table 1** are from Phase I of this project (**Reference 1**). Site locations are presented in **Figure 4** with an overview of each reach illustrated in **Figure 5** through **Figure 7**.

Reach	Reach Length (ft)	100-yr Discharge (cfs)	Structure Present	Cross Sections
Wisdom	4,210	6,980	Yes	7
SCS	6,400	13,300	No	5
Melrose	5,010	17,200	Yes	8

Table 1. List of modeled reaches

The Wisdom reach is located immediately west of the town of Wisdom (**Figure 5**). The Big Hole River exhibits a minimal slope through the reach with a meandering channel and wide floodplains. The channel bottom consists of small gravels while the floodplains consist of grasslands and scattered willows. In the middle of the modeled reach, the Big Hole River is spanned by MT Hwy 43 in the form of a 214’ four span bridge. The bridge was modeled using the survey and 5-m data sources. However, there was not a discernible road surface present in the 10-m, 30-m, and 30-m SRTM data to allow for the inclusion of the bridge in the model.

The SCS reach (shown in **Figure 6**) is located at the upstream end of the middle reach of the Big Hole River which was previously modeled by the Soil Conservation Service (SCS), now called the Natural Resources Conservation Service (NRCS), in 1986. Throughout the SCS reach, the Big Hole River consists of a few channel splits but is relatively straight as it steepens in slope before entering the canyon stretch of the river. The channel substrate is slightly larger than that experienced throughout the Wisdom reach and the wide floodplains exhibited by the river in the upstream reaches begin to narrow as they are constricted by the valley walls. The floodplains are predominately grassland with locations of brush and leafy vegetation found adjacent to the river.

The Melrose reach is located immediately southwest of the town of Melrose (**Figure 7**). At this location, the Big Hole River is comprised of two large, slightly meandering channels. The channel substrate is predominately comprised of small gravels and large cobbles. The wide floodplains are predominately grassland accompanied by scattered locations of willows and sparse growths of large cottonwood trees. Both channels of the Big Hole River at Melrose are spanned by Trapper Creek Road. The west channel is spanned by a 98’ two span bridge while the east channel is spanned by a 216.5’ two span bridge. Similar to the Wisdom reach, the bridges were only modeled using the survey and 5-m data sources. Again this was due to that fact that the 10-m, 30-m, and 30-m SRTM data sources were too coarse to represent the road surface.

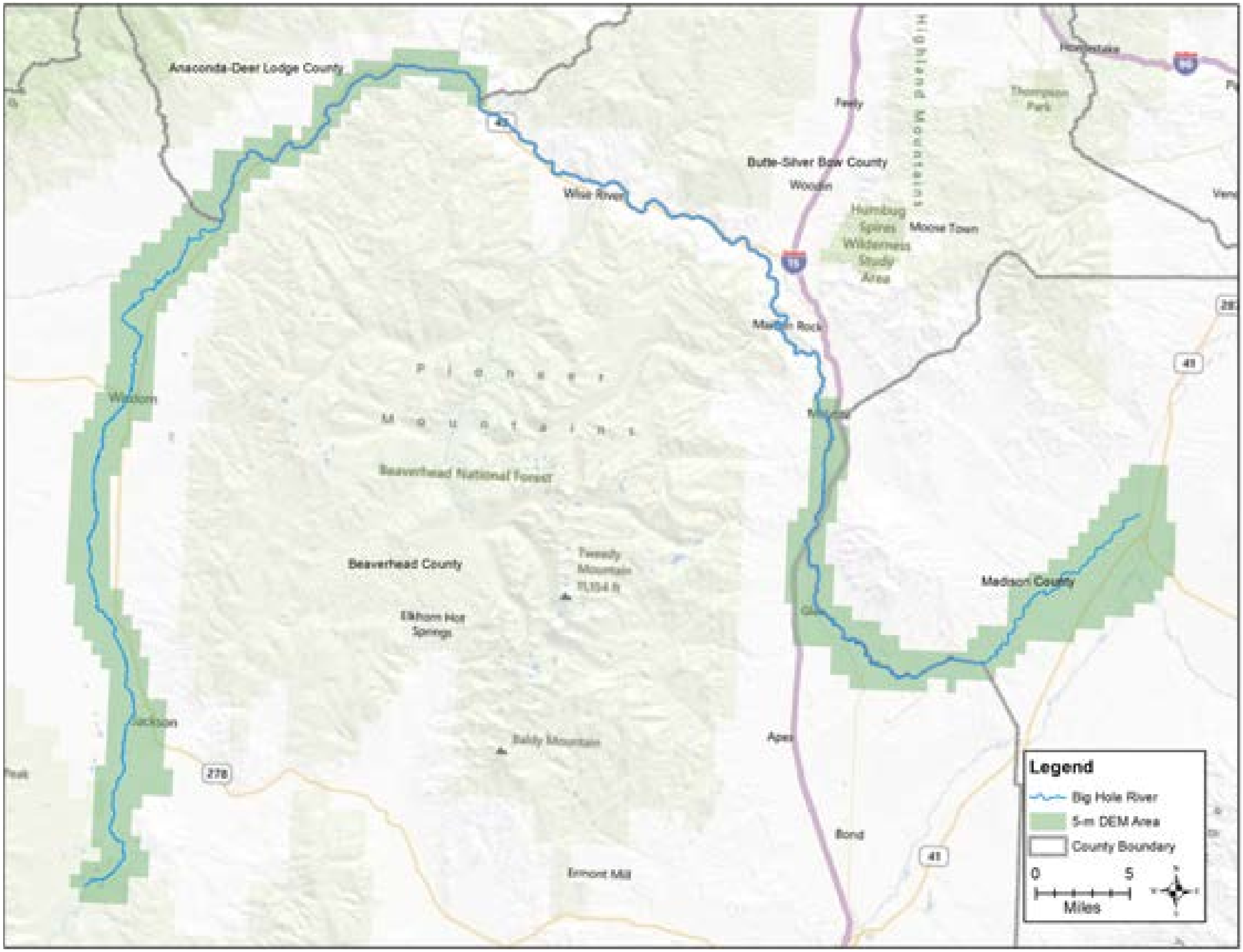

Figure 3. **Encompassed area of the 5-m IFSAR data**

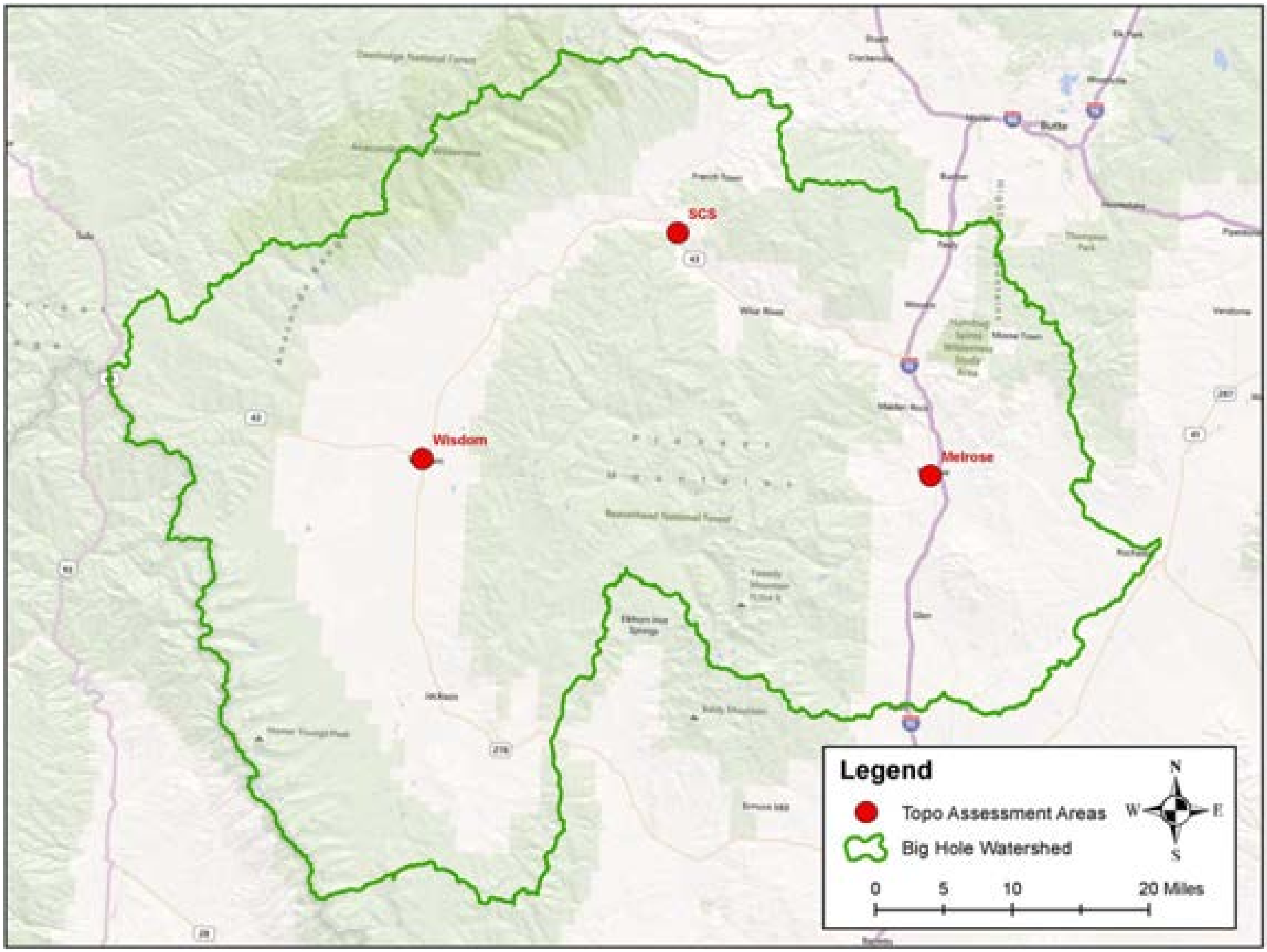

Figure 4. **Location of topographic assessment areas within the Big Hole River watershed**

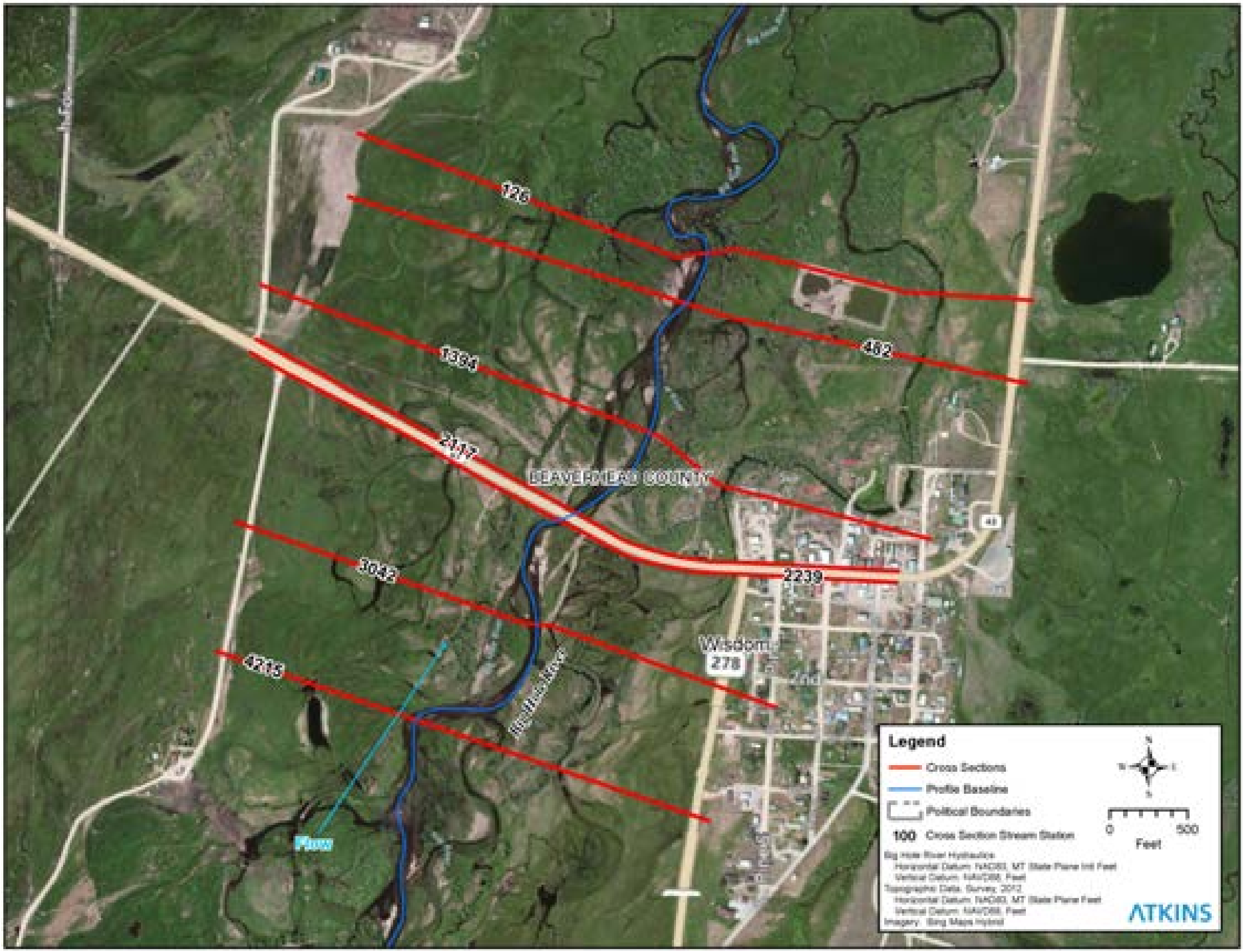

Figure 5. Overview of the Wisdom reach

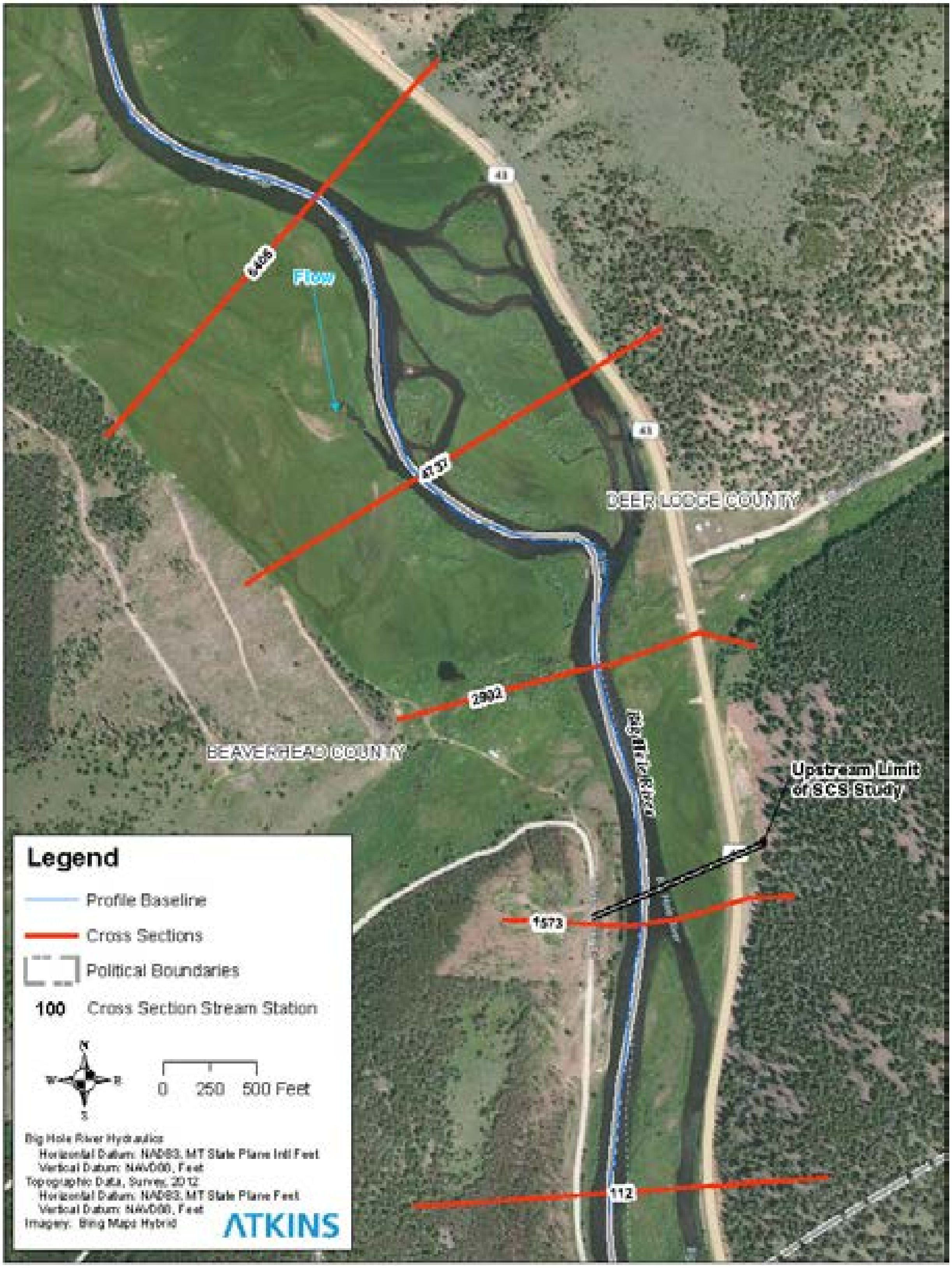

Figure 6. Overview of the SCS reach

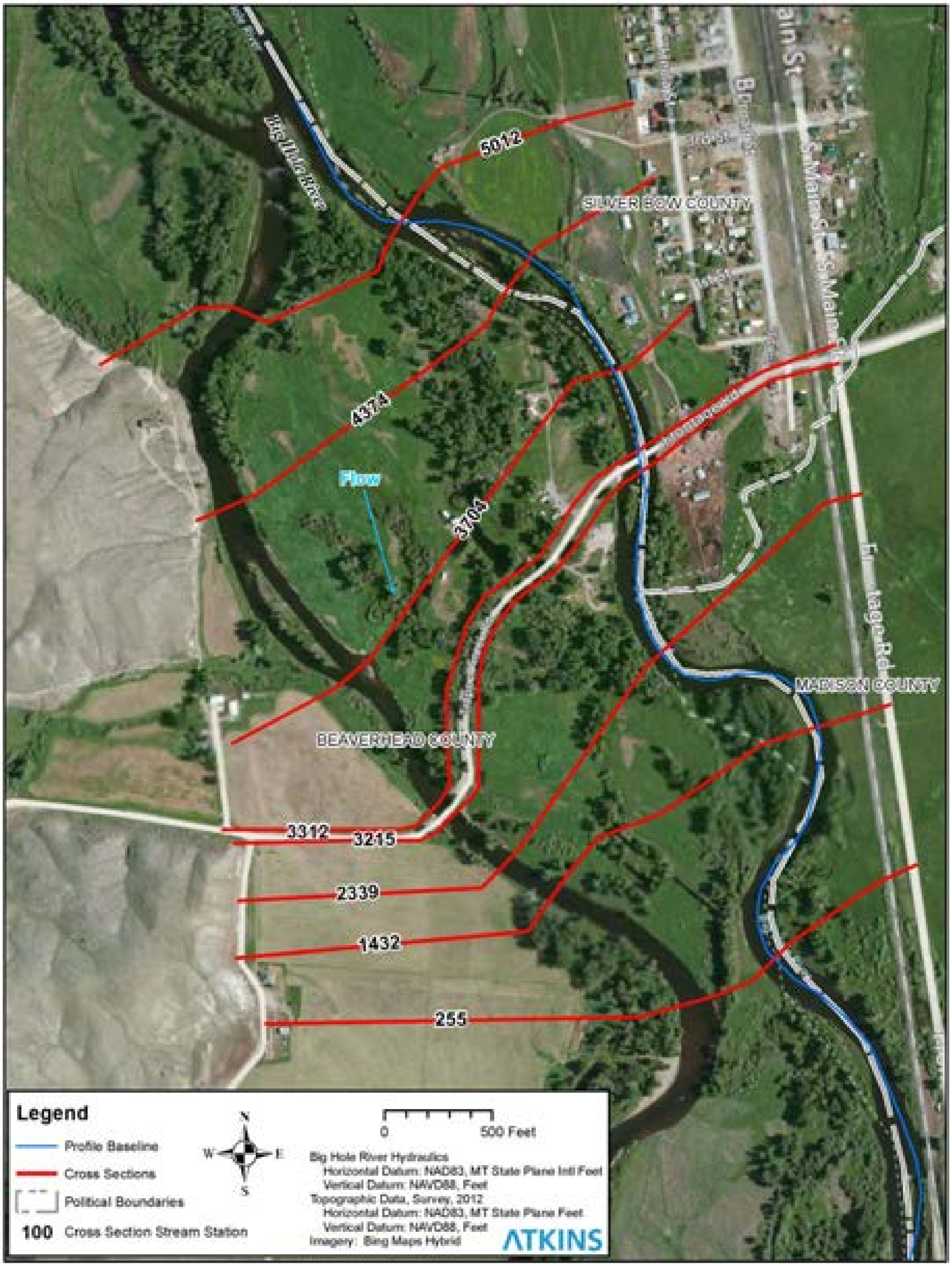

Figure 7. Overview of the Melrose reach

Upon choosing the three assessment reaches, a survey of the proposed cross section locations for each reach was performed. The field survey data was collected by PCI on July 3 – July 12' 2012 as follows:

Projection:	Montana State Plane	<u>Units</u>
Datum:	Horizontal – MT 2500 St Pl NAD83 CORS96	International feet
	Vertical – NAVD88,	US survey feet

In total, survey data was collected for 20 cross sections and three (3) crossings. Cross sectional survey data was collected in order to encompass the assumed 0.2-percent-annual-chance (500-year) floodplain. Data was collected using survey-grade GPS equipment with sub-centimeter accuracy. Details of the collected survey data are included in **Appendix E**. These survey data served as the basis for determining the deviation from "true elevation" for the other topographic data sources.

The surveyed cross sectional geometries were then imported into the US Army Corps of Engineers HEC-RAS Version 4.1.0 hydraulic model in order to perform the steady state backwater calculations through each reach. HEC-RAS (RAS) is widely regarded as the industry standard for one-dimensional hydraulic modeling and is a nationally accepted model for performing hydraulic analyses.

Upon entry of the georeferenced cross sections into the RAS model, assignments of the Manning's 'n' roughness values were assigned. The specific Manning's values were assigned based upon a combination of field visits and 2011 aerial photography. The horizontal breaks in Manning's values were assigned based upon 2011 aerial photography. Utilized Manning's values for each reach are listed in **Table 2**.

Reach	Manning's Value	
	Channel	Overbanks
Wisdom	0.03	0.04
SCS	0.03	0.04 - 0.045
Melrose	0.03	0.04 - 0.06

Table 2. Utilized Manning's values

The assigned 1-percent-annual-discharges of each reach were taken from the "Flood Discharge-Frequency Analysis for the Big Hole River, Montana, Hydrologic Analysis Report" submitted in April of 2012 by Atkins for Phase I of this project.

Upon completion of the Survey RAS model, the remaining topographic sources were employed in order to create separate model geometries. Utilizing the same cross section locations created for the Survey model, a separate model was created to describe the geometries of each topographic source. When utilizing the 10-m, 30-m, and 30-m SRTM data, the stream and overbank lengths, Manning's values, and horizontal Manning's breaks remained consistent to those of the Survey model in representing the channel and roughness breaks as defined by the aerial imagery and survey data. This was due to the lack of a discernible channel within the 10-m, 30-m, and 30-m SRTM source data. Varying the bank stations in the model affects the conveyance calculations and the resultant profiles. Hence, by consistently assigning the bank stations, any difference in the results is directly related to the difference in the geometry. It should be noted that the 5-

m data did reflect the actual cross sectional geometries. Hence, when utilizing the 5-m data, the bank station assignments were placed to reflect the channel description present within the cross sectional geometry. The aforementioned variables of stream and overbank lengths, Manning's values, locations of Manning's breaks, and discharges remained constant in each model to ensure that any difference in the results could be directly attributed to the change in topographic sources. It should be noted that each reach was assigned a normal depth downstream boundary condition with the slope calculated from the channel slope of each respective data source. The slopes utilized for the normal depth calculations of each data source and assessment area are listed below in **Table 3**.

Reach	Normal Depth Slope (ft/ft)				
	Survey	5-m	10-m	30-m	30-m SRTM
Wisdom	0.00489	0.00322	0.00006	0.00016	0.00375
SCS	0.00249	0.00224	0.00066	0.00070	0.00112
Melrose	0.00200	0.00279	0.00249	0.00198	0.00279

Table 3. Slopes utilized for the normal depth boundary conditions

Where a bridge was present within the model, the span and chord depth was constant for all applicable topographic sources. However, the high chord elevations were dependent upon the elevations taken from the respective topographic source. As mentioned, the 10-m, 30-m, and 30-m SRTM data sources were too generalized to create a road surface at a higher elevation than the bounding cross sections. Therefore, no structures were modeled within the 10-m, 30-m, and 30-m SRTM geometries.

4. Results

4.1. Hydraulic Structure Inventory and Assessment

The hydraulic structure inventory information was compiled into an ESRI database where adding the point feature class to an MXD shows the point location spatially. When the IDENTIFY tool is used to identify a point feature, attributes of the structure are displayed. Additionally, an attachment file is linked to the IDENTIFY window that, when opened, links the spatial point to a PDF document containing an aerial image and annotated field photographs of each structure. An example PDF for S_ID 6 is shown as **Figure 8** and **Figure 9**. The attributed inventory of the assessed hydraulic structures is presented in **Appendix A**. Note that due to lack of landowner permission, a total of nine structures (at three separate locations) could not be evaluated in the field. The structures are 13, 14, 30, 31, 32, 33, 39, 40, and 41 as indicated in the structure identification field (S_ID) of the point feature class.

The data contained within the point feature class contains both numbers and text. Numeric field types were used for most bridge and culvert dimensions however some were created as string, as described earlier. An example is S_ID 24 where a hybrid structure consists of a bridge and an immediately adjacent culvert. Another example is S_ID 6 where a steel truss bridge is supported by concrete piers and abutments along the channel margins. The deck thickness is variable for this structure as well.

Enough information has been collected to define these structures in a hydraulic model. If it is decided that the structures are to be incorporated into the hydraulic analysis of the project, some assumptions shall be required. For example, the height of the low chord above channel invert should be estimated from field photographs. Also, pier location along the cross section must be estimated.

Figure 8. Page 1 of 5 of the photographic inventory for Structure ID 6 (aerial image)

Figure 9. Page 2 of 5 of the photographic inventory for Structure ID 6 (upstream face of bridge)

4.2. Accuracy of Topographic Data Sources

In conjunction with the hydraulic accuracy of the various data sources, the absolute accuracy of each data source was also measured. This was done by comparing spot elevations of each topographic source with the collected survey points. The results of the spot elevation comparisons are presented below in **Table 4**. Upon review of the elevation comparisons, it is apparent that the 5-m source is more accurate than the other data sources.

Data Source	Ave Error (±ft)	Std Dev (ft)
5-m	2.01	1.98
10-m	5.49	5.59
30-m	5.79	5.58
30-m SRTM	6.42	6.22

Table 4. Results of the elevation comparisons

Further description of the accuracy for each of the reviewed topographic sources is presented in the following sections.

4.2.1. 5-meter DEM

The 5-m DEM utilized in the study was purchased by the DNRC from Intermap Technologies Corp. and received in June of 2012. Upon comparison of the 5-meter data with that of the survey data, it was apparent that the geometry and general shape of the surveyed cross section was represented fairly well by the 5-m data. The actual differences in elevations of the 5-m and survey datasets varied by as much as approximately eight feet in the channel to roughly 14 feet in the steeper slopes of some overbank sections. However, these large discrepancies were typically found on steeper hill side slopes and were generally isolated to the SCS reach. Besides the elevation discrepancies witnessed on the steeper slopes, the downstream end of the SCS reach displayed relative large differences in elevation. Within the SCS reach, the 5-m DEM also displayed elevations that were less than those surveyed. Intermap was consulted on this issue and concluded that while the error was still within the accuracy tolerance of the purchased product, the problem was an isolated result of editing the data to create a hydro-enforced dataset. The correspondence between Atkins, DNRC, and Intermap in regards to the issue is included within **Appendix F**. On average, the 5-m data source showed a difference of ± 2.01’ with a standard deviation of 1.98’ when compared to the survey data. A comparison of each cross section and modeled profile is displayed in **Appendices B - D**.

4.2.2. 10-meter USGS DEM

The 10-m DEMs employed in the study were downloaded via the USGS Seamless Data Server in March of 2012. For nearly all of the modeled cross sections, the vertical and horizontal accuracy of the 10-meter USGS DEM was poor. The 10-m USGS topographic source typically had much higher elevations than the survey data and rarely gave a good representation of the cross sectional geometries exhibited by the survey data. The geometry of the 10-m data was typically characterized by a large swale with an approximate width of the entire floodplain, if not larger. The 10-m DEM rarely displayed the presence of a channel and when it did, the DEM never exhibited a channel description at the correct location. When there was a channel present within the 10-m geometry, it appeared to be remnants of a poor interpolation when the DEM was initially created as the channel was typically located at the base of a steep slope. The 10-m DEM also seemed to misrepresent the developed areas within Wisdom and Melrose. It is assumed that this error was produced when the DEMs were created. On average, the 10-m data source has a difference of ± 5.49’ with a standard deviation of 5.59’ when compared to the corresponding survey elevations. A comparison of each cross section along with the profile of each modeled reach is displayed in **Appendices B - D**.

4.2.3. 30-meter USGS DEM

The 30-m USGS DEMs were downloaded via the USGS Seamless Data Server in June of 2012. The 30-m USGS DEM also represented the survey data poorly. Much like the 10-m DEM the 30-m data was consistently higher than the surveyed channel and never approximated the relative geometry of the surveyed channel and floodplain. It was noticed that 30-m USGS DEM closely approximated the 10-m DEM at nearly every cross section. Given that the 10- and 30-m datasets were derived from the same data source, some similarities were expected. Further discussion with USGS Earth Resources Observation and Science (EROS) Center revealed that the 30-m DEM is merely resampled from the 10-m DEM. This means that the 10-m dataset is included within the 30-m data. The only difference is the resolution between the products. Similarly to the 10-m DEMs, the 30-m DEM appears to grossly distort the developed areas of the modeled communities (Wisdom and Melrose). When compared to the survey data, the 30-m data source has an average difference of ± 5.79’ with a standard deviation of 5.58’. A comparison of each cross section along with the profile of each modeled reach is displayed in **Appendices B - D**.

4.2.4. 30-meter SRTM DEM

The 30-m SRTM DEM was downloaded via the USGS’s Earth Resources Observation and Science (EROS) Center in July of 2012. The 30-m SRTM DEM compared poorly with the survey data. The DEMs utilized for the study, especially the Wisdom reach, seemed to be filled with ‘noise’ as there were no consistent elevations or realistic trends in slopes and geometry. The profiles of the SRTM data were unrealistic as well as the slope of the reaches sporadically increased and decreased. On average, the 30-m SRTM data source has a difference of ± 6.42’ with a standard deviation of 6.22’ when compared with corresponding survey elevations. A comparison of each cross section along with the profile of each modeled reach is displayed in **Appendices B - D**.

4.3. Hydraulic Modeling

Upon completion of modeling each reach with the various topographic data sets, the results of the hydraulic calculations were compared with the results produced by the survey data. Results comparisons focused on the resultant water surface elevation (WSEL) and mapped top width of each location as these variables are the primary focus of Approximate level floodplain studies. It should be reiterated that the respective 100-year discharge for each assessment area was utilized for the comparisons. **Table 5** through **Table 7** tabulate the minimum, maximum, and average differences in minimum cross sectional elevation, WSELs, and top widths realized in each reach by the respective data sources. As seen in **Table 5** through **Table 7**, the data sources that more closely approximate the minimum elevation of the cross sections, resulted in the more accurate depiction of not only the calculated WSEL but also the resultant top width as well. It is apparent that the 5-m topographic source is far superior to the 10-m, 30-m, and 30-m SRTM data sources. The 5-m results show that through each studied reach, it compares to the survey data better than any of the other utilized sources. As stated, the 10-m and 30-m models compared similar to each other with relatively minor differences found between the data sources and the results. The 30-m SRTM data displayed inconsistent results as it showed better results than the 10-m and 30-m data for some reaches; it also showed large error values that were more than five times that of the 5-m data.

Reach	5-m			10-m			30-m			30-m SRTM		
	Min (ft)	Max (ft)	Ave (ft)	Min (ft)	Max (ft)	Ave (ft)	Min (ft)	Max (ft)	Ave (ft)	Min (ft)	Max (ft)	Ave (ft)
Wisdom	0.14	1.69	0.74	3.51	8.69	6.25	3.60	8.54	6.30	2.79	10.44	7.11
SCS	1.38	6.83	4.12	0.64	11.77	6.06	4.14	11.70	7.80	3.19	15.84	9.82
Melrose	0.91	4.24	2.67	2.09	19.46	9.03	0.70	19.50	8.82	0.83	6.10	3.66

Table 5. Summary of differences (ft) in minimum cross section elevation for each reach and topographic source

Reach	5-m			10-m			30-m			30-m SRTM		
	Min (ft)	Max (ft)	Ave (ft)	Min (ft)	Max (ft)	Ave (ft)	Min (ft)	Max (ft)	Ave (ft)	Min (ft)	Max (ft)	Ave (ft)
Wisdom	0.97	2.30	1.44	0.13	7.21	3.54	0.62	6.04	3.27	1.63	11.15	7.84
SCS	2.61	6.85	4.68	2.93	13.50	8.22	6.60	13.25	9.14	3.04	7.47	5.13
Melrose	0.03	1.89	0.67	0.10	15.45	4.50	0.03	15.38	4.36	0.05	2.91	1.65

Table 6. Summary of differences (ft) in calculated WSEL for each reach and topographic source

Reach	5-m			10-m			30-m			30-m SRTM		
	Min (%)	Max (%)	Ave (%)	Min (%)	Max (%)	Ave (%)	Min (%)	Max (%)	Ave (%)	Min (%)	Max (%)	Ave (%)
Wisdom	0.8	64	17	0.6	69	42	8.5	62	39	27	193	99
SCS	0.4	46	19	22	71	44	2.6	83	42	19	60	36
Melrose	0.2	13	4.5	4.2	126	26	1.7	77	26	2.7	130	29

Table 7. Summary of differences (%) in resultant top widths for each reach and topographic source

When reviewing the summarized results of all reaches, as shown in **Table 8** below, it is further reinstated that the 5-m data far outperforms the other data sources. This is displayed in **Table 9** as 70% of the 5-m cross section calculated a WSEL within 2’ of the survey data while the 10-m, 30-m, and 30-m SRTM data only show 40%, 45%, and 30%, respectively. The unreliability of the 10-m, 30-m, and 30-m SRTM data sources is highlighted in **Table 9** as it shows that the 10-m, 30-m, and 30-m SRTM models have respectively 20%, 20%, and 5% of the calculated WSELs resulting in more than 10’ of difference from the survey data. The unreliability of these data sources is again displayed in **Table 10** as a large percentage of the resultant top widths showing errors greater than 50% of the resultant top widths of the survey models. While 65% of the locations within the 5-m models have a top width with a difference of less than 10%, the other topographic datasets show a large percentage of locations having differences in top widths greater than 50%.

	Percentage of Cross Sections with a Minimum Ground Difference of:				
	< 1'	< 2'	< 5'	< 10'	> 10'
5 meter	30%	55%	90%	100%	0%
10 meter	5%	5%	35%	85%	15%
30 meter	5%	5%	30%	85%	15%
SRTM	10%	15%	40%	75%	25%

Table 8. Summary of error for minimum ground elevations, all reaches

	Percentage of Cross Sections with a WSEL Difference of:				
	< 1'	< 2'	< 5'	< 10'	> 10'
5 meter	40%	70%	85%	100%	0%
10 meter	15%	40%	60%	80%	20%
30 meter	15%	45%	60%	80%	20%
SRTM	10%	30%	60%	95%	5%

Table 9. Summary of error for calculated water surface elevations, all reaches

	Percentage of Cross Sections with a Top Width Difference of:			
	< 10%	< 20%	< 50%	> 80%
5 meter	65%	85%	95%	0%
10 meter	30%	35%	75%	5%
30 meter	20%	40%	75%	5%
SRTM	15%	25%	65%	25%

Table 10. Summary of error for resultant top widths, all reaches

5. Conclusions

5.1. Hydraulic Structure Assessment

It is a generally accepted practice to exclude hydraulic structures when performing an Approximate level hydraulic analysis. This is largely due to the low resolution and lack of accuracy inherent within the topographic data sources normally employed for Approximate studies. The topic of whether the structures inventoried should be employed during the Big Hole River flood study is debatable and also dependent upon the results of the topographic assessment. Since the Upper Big Hole River valley is flat and broad, subtle increases in backwater elevation translate to a potentially significant increase in the horizontal extent of the floodplain upstream of the structure. Conversely, the middle section of the Big Hole River flood study located in the canyon will likely show less backwater effect in the final delineated floodplain. Since the canyon is steep and incised, many of the bridges are high above the channel and the floodplain margins are narrow. Increases in flood elevation would not produce significant increases in the horizontal extent of the mapped floodplain. Similar to the Upper Big Hole River valley, the Lower Big Hole River valley transitions from the canyon section to express its broad, flat floodplain where similar backwater affects may be expected. For most of the stream crossings throughout the entire study area, roadway embankments are visible in the 5-m DEM. Meaning that the element size of the 5-m DEM is small enough that the increased elevations of the roadway embankment are presented within the data. The coarseness of the 10- and 30-m DEMs does not allow for the embankment to be realized within the topographic data. The differences in the representation of the roadway embankments for the 5-m and 10-m DEMs are presented in **Figure 10** and **Figure 11**, respectively.

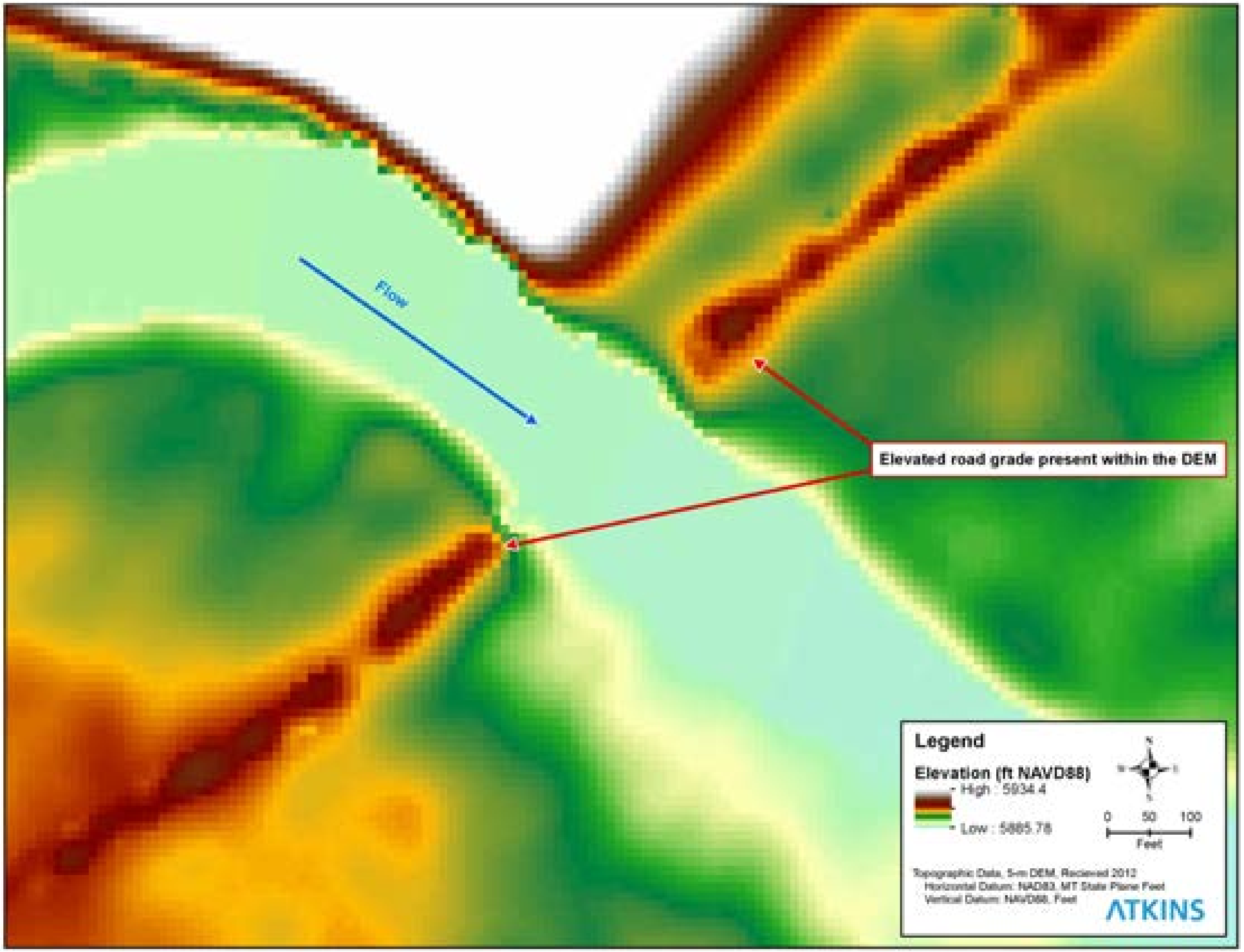

Figure 10. Elevated road grade within the 5-m DEM

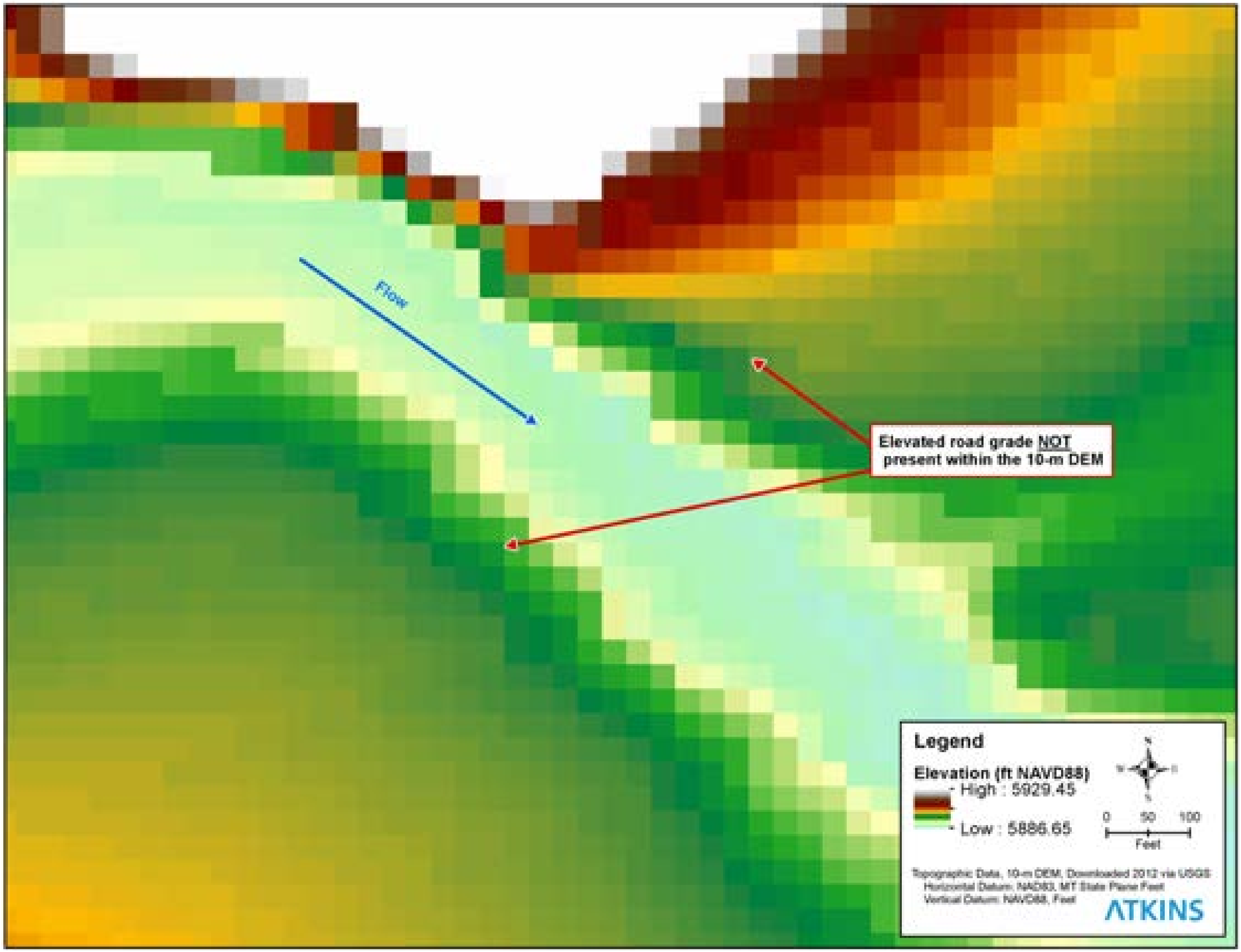

Figure 11. Elevated road grade within the 10-m DEM

Utilization of the more refined 5-m DEM presents an opportunity to incorporate hydraulic structures without collecting additional survey data. Since the bridge approaches are defined in the DEM, all other pertinent dimensions can be related to the approach or deck elevation. However, what seems like a good opportunity may also lead to further deviations from reality. The 5-m DEM remains fairly coarse, although a significant improvement from the 10-m DEM. It is important to note that DEM elevations are averaged over the area of the grid cell. Since most bridges are between one and three elevation grid cells wide, the lesser elevations of the natural ground and the embankment side slope will often reduce the elevation of the grid cell from the true roadway elevation. This will often lead to undesirable circumstances when creating the relative bridge geometry. Hence, simply subtracting the deck thickness from the 5-m DEM deck elevation may produce a low chord elevation that leaves very little flow area or even results below the ground elevation. For example, inclusion of the bridge geometry within the 5-m Melrose geometry created a low chord with an unrealistic low elevation. The open area of the bridge represented in the 5-m DEM equaled 373 ft^2 compared to the 2670 ft^2 of the surveyed geometry. While the difference was not as severe, the bridge crossing modeled within the Wisdom reach exhibited a decrease in the available flow area. The more accurate representation for the Wisdom bridge is likely due to it being much larger with wider bridge encroachments and subsequently more prevalent in the 5-m DEM than the hydraulic crossing of the Melrose reach. This example illustrates that adding detail and complexity to a model based on a set of relative measurements and assumptions may not produce better results and will only impact a short reach upstream of the structure. A better option for small crossings where backwater is expected may be to place or survey a cross section on top of the embankment to approximate the top of roadway and likely constriction and expansion of the floodplain. An option for larger crossings and bridges would be to supplement the 5-m DEM geometry with a surveyed structure data. This would assist to decrease the affects created by the generalized structure geometry of the 5-m DEM. For most highway crossings, defining a structure would not be worthwhile since most will not impose backwater due to the low chords being elevated above the assumed water surface profiles. For these reasons, Atkins recommends not allocating additional resources to incorporate structures in the approximate flood study.

In the event that LiDAR is collected for the area and the hydraulic models are to be enhanced with superior topographic information, the structure inventory will become highly useful. The amount of survey required is reduced, since these relative measurements may be related to a datum and used in the detailed flood study. Furthermore, the engineer can spend less time at each structure since photographs and measurements have already been collected.

5.2. Topographic Data Assessment

As displayed above in the comparisons of the results, the accuracy of the resultant WSELs and floodplain top widths are directly related to the accuracy of the topographic data source. From the 5-m, 10-m, 30-m, and 30-m SRTM topographic data sources of the Big Hole River, it is apparent that the 5-m topographic source performs the best as it not only displays a closer approximation of the actual cross sectional geometry, but it also produces resultant WSELs and top widths that are far more accurate than the other data sources. Hence, it is recommended that the 5-m data be utilized for future hydraulic studies within the Big Hole River where survey data is not available. It is also recommended, when financially possible, that all future Zone A studies be performed with data similar to that of the 5-m source utilized in this study. As seen in the review of the hydraulic results of **Tables 5 - 10**, utilization of more generalized 10-m and 30-m data sources can result in gross misrepresentations of the WSELs and top widths calculated for Zone A floodplain studies.

6. References

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Appendices

Appendix A. Hydraulic Structure Inventory

Structure ID	Location ID	Lat_DD	Long_DD	River Station[1] (mi)	Model Station East[2] (ft)	Model Station West[3] (ft)	Type	RoadNm	Width_Span	CulvHt	DeckWidth	Inlet2Deck	Out2Deck	Length
1	1	45.5481	-112.3650	1.8	9474		Bridge	Melrose Rd	257		34.0			
2	2	45.4978	-112.4380	7.6	39995		Bridge	Burma Rd	208		26.0			
3	2	45.5003	-112.4400	7.6	39995		Bridge	Burma Rd	149		26.0			
4	3	45.4684	-112.6640	25.1	132692		Bridge	Burma Rd	100		26.0			
5	3	45.4683	-112.6670	25.1	132692		Bridge	Burma Rd	158		26.0			
6	4	45.5266	-112.7020	30.9	163260		Bridge	Frontage Rd	236		21.7			
7	5	45.5272	-112.7020	31.0	163504		Bridge	RR east of I15	239		14.5			
8	6	45.5302	-112.7030	31.2	164625		Bridge	I15 Northbound	444					
9	6	45.5306	-112.7040	31.2	164780		Bridge	I15 Southbound						
10	7	45.5473	-112.6930	32.6	172242		Bridge	Brownes Gulch Rd	171		19.0			
11	8	45.6222	-112.6900	38.9	205431		Bridge	Trapper Creek Rd	98		18.0			
12	8	45.6267	-112.6870	38.9	205431		Bridge	Trapper Creek Rd	217		26.0			
13	9	45.6500	-112.6950	41.0			Bridge	Private						
14	9	45.6516	-112.7030	41.0				Private						
15	10	45.7016	-112.7360	47.3			Bridge	Maiden Rock Rd	197		18.0			
16	11	45.7575	-112.7810	53.0			Bridge	MT Hwy 43	304		36.0			
17	12	45.7597	-112.8020	54.4			Bridge	Pump House Rd	228		19.0			
18	13	45.7857	-112.9150	61.4			Bridge	Jery Creek Rd	200		18.5			
19	14	45.8507	-113.0690	71.7			Bridge	MT Hwy 43	327		32.0			
20	15	45.8077	-113.3130	89.0		469920	Bridge	MT Hwy 43	235		31.5			
21	16	45.6185	-113.4570	111.5		588720	Bridge	MT Hwy 43	214		32.0			
22	17	45.5671	-113.4820	117.2		618816	Bridge	Rock Creek Rd	23		20.0			
23	17	45.5670	-113.4850	117.2		618816	Bridge	Rock Creek Rd	30		20.0			
24	17	45.5670	-113.4870	117.2		618816	Culvert/Bridge	Rock Creek Rd	8'/22.5'	8.0	13'/17'	1.2	6.0	20.2
25	18	45.5267	-113.4840	121.1		639408	Bridge	Twin Lakes Rd	81		26.0			
26	18	45.5265	-113.4860	121.1		639408	Culvert	Twin Lakes Rd	13	7.5	20.0	1.0	3.5	24.5
27	19	45.4776	-113.4870	125.8		664224	Bridge	Big Lake Creek Rd	61		20.0			
28	19	45.4775	-113.4810	125.8		664224	Bridge	Big Lake Creek Rd	50		18.0			
29	19	45.4774	-113.4790	125.8		664224	Culvert	Big Lake Creek Rd	6	4.0	23.0	5.0	2.0	30.0
30	20	45.4591	-113.4790	127.4		672672		Private						
31	20	45.4590	-113.4790	127.4		672672		Private						
32	20	45.4586	-113.4750	129.7		684816		Private						
33	20	45.4593	-113.4750	131.3		693264		Private						
34	21	45.4405	-113.4570	133.0		702240	Bridge	Big Swamp Creek Rd	98		18.5			
35	22	45.4230	-113.4490	133.0		702240	Bridge	Private	72		16.5			
36	23	45.4052	-113.4410	137.0		723360	Bridge	Little Lake Creek Rd	51		21.0			
37	23	45.4052	-113.4440	140.0		739200	Bridge	Little Lake Creek Rd	36		20.0			
38	24	45.3610	-113.4410	142.2		750816	Bridge	Miner Lake Rd	82		30.0			
39	25	45.3427	-113.4430	143.9		759792		Private						
40	26	45.3308	-113.4400	143.9		759792		Private						
41	27	45.3077	-113.4510	143.9		759792		Private						
42	28	45.2911	-113.4510	145.6		768768	Bridge	Private	26		20.0			
43	28	45.2912	-113.4520	147.9		780912	Culvert	Private	4		11.0	5.0	4.0	20.0
44	28	45.2912	-113.4530	149.2		787776	Culver	Private	3	2.5	14.0	3.0	2.5	19.5
45	29	45.2757	-113.4400	127.4		672672	CONSPAN	Skinner Meadows Rd	10	6.5	15.0	5.0	7.0	27.0
46	30	45.2524	-113.4450	127.4		672672	Bridge	Saginaw Rd	34		14.0			
47	31	45.2453	-113.4600	138.8		732864	Bridge	Private	40		16.0			
D1	32	45.7640	-112.7880	53.6			Diversion							

[1]River station in reference to the mouth of the Big Hole River.
[2]River station in reference to the East HEC-RAS hydraulic model completed under Task 2; references the mouth as Sta. 0
[3]River station in reference to the West HEC-RAS hydraulic model completed under Task 2; references the Butte-Silver Bow Co. boundary as Sta. 0

Structure ID	DeckThick	GrdRlHt	EntType	Material	AbutType	PierNo	PierWidth	PierType	BW_Potent
1	8.000	1.50		Concrete	vertical concrete	1	2.5	Sharp nose	Medium: ROB is prob not accessed; LOB is low and broad
2	4.000	2.67		Concrete	vertical concrete	2	2.5	Sharp nose	Medium: perched bridge with low embankments
3	3.500	2.75		Concrete	vertical concrete	1	2.5	Sharp nose	Low: Structure spans a side channel and is parallel to river
4	5.670	2.50		Concrete	concrete spill through	0			Medium: high embankments block floodplain but split channel
5	4.000	2.42		Concrete	concrete spill through	1	6.7	Cylinder	Medium: river left is low; river right is blocked
6	Core 54"/48" tress	2.83		Concrete to piers/Steel truss	vertical concrete	2		Sharp nose	Medium; spans bankfull width; FP blocked on both sides
7	6.300	3.50		Steel truss	vertical concrete	2	6.5	Square Nose	Medium; spans bankfull width; FP blocked on both sides
8	5.170	3.17		Steel	vertical concrete	4	8'cyl/53"sq	Cylinder	Medium; spans bankfull width; FP blocked on both sides
9	5.170	3.17		Steel	vertical concrete	4	8"cyl/53"sq	Cylinder	Medium; spans bankfull width; FP blocked on both sides
10	2.080	3.08		Steel truss	vertical concrete	0			
11	2.580	2.42		Steel	steel vertical	1	2.5	Sharp nose	Medium: low ground in both overbanks but bridge doesn’t span bankfull channel
12	5.040	2.25		Concrete	vertical concrete	1	5.0	Cylinder	Medium: Low ground river right between bridges
13									Low
14									
15	2.410	2.67		Steel truss	vertical concrete	0			Medium: River right is low
16	6.000	2.21		Concrete	vertical concrete	2	5.0	Sharp nose	Low: Spans floodplain
17	1.125	4.42		Steel truss	vertical concrete	1	4'/5.5'	Sharp nose	Low
18	3.790	2.33		Concrete	vertical concrete	3		Sharp nose	Medium
19	7.250	2.67		Concrete	vertical concrete	2	2.5	Sharp nose	High: floodplain blocked
20	3.580	2.67		Concrete	vertical concrete	3	2.5	Sharp nose	High: floodplain blocked
21	3.000	2.75		Concrete	vertical concrete	3	2.5	Sharp nose	High: floodplain blocked
22	3.750	2.50		Steel	vertical steel/vert wood/?	0			Medium
23	2.670	2.67		Steel	vertical steel	0			Medium
24	4"/24"		Projecting	Steel/Wood	vertical wood	0			Medium
25	2.670	2.25		Concrete	vertical	0			Medium
26	0.330		Mitered	Corrugated Metal					Low
27	2.500			Steel		1		Group of cylinders	Medium
28	2.670	2.25		Steel		1		Group of cylinders	Low
29	0.330		Projecting	Corrugated Metal					Low
30									
31									
32									
33									
34	2.330	3.33		Steel		2	1.0	Group of cylinders	Low: Bridge is perched with ROB at grade with FP
35	1.500			Wood		3	1.0	Group of cylinders	Low: Bridge is perched with overbanks at grade with FP
36	2.750	2.67		Steel		0			Medium to Low: Bridge is perched with ROB at grade with FP
37	2.330	3.50		Steel		0			Medium
38	2.800	2.33		Concrete		0			Medium: Single bridge for a wide floodplain
39									
40									
41									
42	1.500			Steel/Wood		0			Low
43	0.250		Projecting	Corrugated Metal					Low
44	0.250		Projecting	Corrugated Metal	Projecting				Low
45	0.330		Projecting	Corrugated Metal					Medium: structure is possibly flanked
46		1.00		Steel/Wood		0			Medium/Low - structure is flanked
47	1.600			Wood		1	5.5	Square Nose	Low
D1									Low

Structure ID	Condition	Date	Notes
1	Excellent	6/20/2012	
2	Excellent	6/20/2012	
3	Excellent	6/20/2012	complex, parallel to main channel
4	Excellent	6/20/2012	split flow potential, very likely
5	Excellent	6/20/2012	potential split flow
6	Fair	6/20/2012	hybrid bridge-concrete outside piers, steel truss inside piers
7	Good	6/20/2012	Subtract 2.5' from deck thickness for span between piers
8	Excellent	6/20/2012	
9	Excellent	6/20/2012	use Northbound data for southbound/identical
10	Fair	6/20/2012	
11	Fair	6/20/2012	riprap failure/erosion on upstream
12	Excellent	6/20/2012	
13		6/20/2012	no access, called caretaker (Elden 530-518-4680), high bridge, minimal fp encroachment
14		6/20/2012	no access, called caretaker (Elden 530-518-4680), high bridge, minimal fp encroachment
15	Good/Fair	6/20/2012	
16	Excellent	6/20/2012	
17	Fair/Poor	6/20/2012	Old pump house steel truss bridge
18	Excellent	6/20/2012	
19	Excellent	6/20/2012	
20	Excellent	6/19/2012	
21	Excellent	6/19/2012	
22	Fair	6/19/2012	
23	Fair	6/19/2012	
24	Fair	6/19/2012	
25	Excellent	6/19/2012	Sand and gravel substrate
26	Fair	6/19/2012	
27	Good/Fair	6/19/2012	
28	Good/Fair	6/19/2012	
29	Good/Fair	6/19/2012	Double barrel CMP
30		6/19/2012	
31		6/19/2012	
32		6/19/2012	
33		6/19/2012	
34	Good	6/19/2012	Thick willows on LOB, Perched bridge
35	Fair	6/19/2012	
36	Good/Fair	6/19/2012	
37	Good/Fair	6/19/2012	Small substrate, perched bridge
38	Excellent	6/19/2012	
39		6/19/2012	
40		6/19/2012	
41		6/19/2012	
42	Fair	6/19/2012	
43	Fair	6/19/2012	Triple barrel
44	Fair	6/19/2012	Perched
45	Good	6/19/2012	Slightly perched
46	Good	6/19/2012	Perched
47	Fair	6/19/2012	Crossing located in a sag; substrate consists of sand and small cobble
D1			Diversion structure

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel from bridge.

Figure 3. View of downstream channel from bridge.

Figure 4. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel from bridge.

Figure 3. View of downstream channel from bridge.

Bighole River Hydraulic Structure Inventory

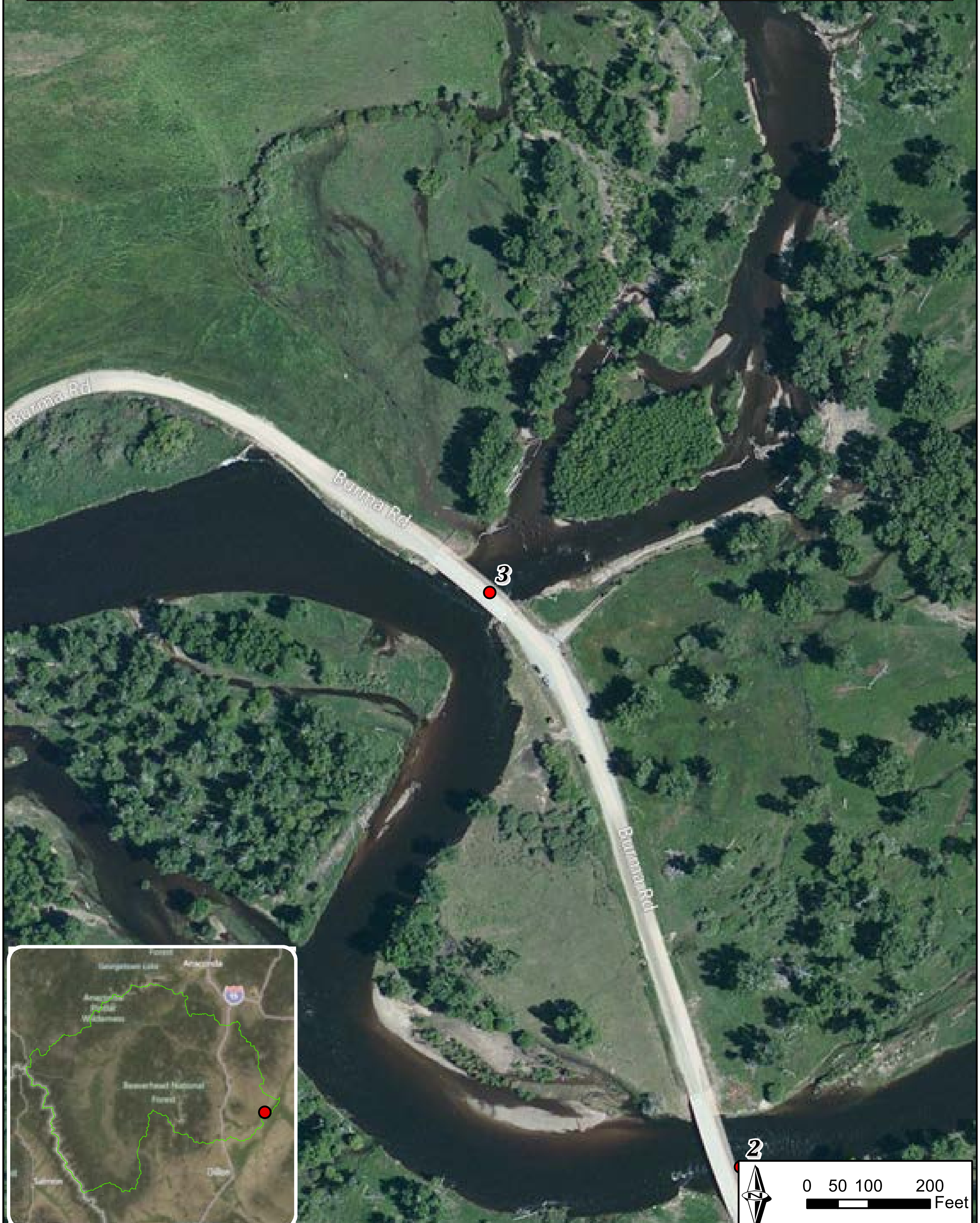


Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel from bridge.

Figure 3. View of downstream channel from bridge.

Figure 4. View of downstream channel from bridge. Channel shown in the above figure does not flow through the bridge but instead continues downstream in a separate channel.

Figure 5. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel from bridge.

Figure 3. View of downstream channel from bridge.

Figure 4. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel from bridge.

Figure 3. View of downstream channel from bridge.

Figure 4. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel from bridge.

Figure 3. View of downstream face at river left.

Figure 4. View of downstream face at river right.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of bridge at river left.

Figure 2. Upstream face of bridge at river right.

Figure 3. View of upstream channel from bridge.

Figure 4. View of downstream channel from bridge.

Figure 5. View of downstream face at river right.

Figure 6. View of downstream face at river left.

Bighole River Hydraulic Structure Inventory

Figure 1. View of upstream face (I-15 north).

Figure 2. Upstream face of bridge (I-15 south)

Figure 3. View of upstream channel from bridge.

Figure 4. View of downstream face at river left.

Figure 4. View of downstream face at river right.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel (river right) from bridge.

Figure 3. View of upstream channel (river left) from bridge.

Figure 4. View of downstream channel.

Figure 5. View of downstream face.

Bighole River Hydraulic Structure Inventory

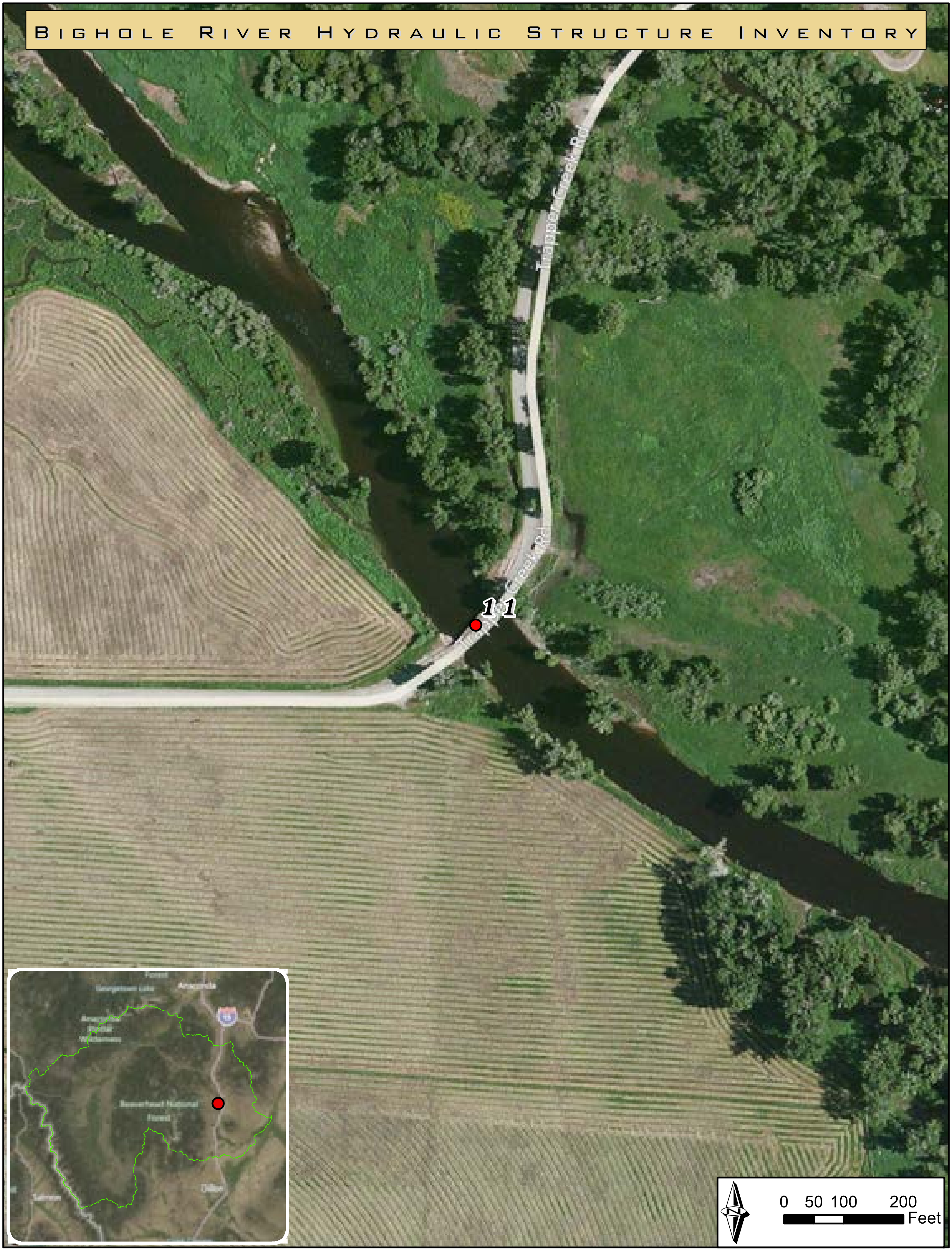


Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel from bridge.

Figure 3. View of downstream channel.

Figure 4. View of downstream face.


Bighole River Hydraulic Structure Inventory
Hecla St
1st St
Broad St
Hecla Plaza St
Frontage Rd
1 2
Feet
0 50 100 200
Anaconda
Beaverhead National Forest
Dillon
Salmon

Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel from bridge.

Figure 3. View of downstream channel from bridge.

Figure 4. View of downstream face.

Bighole River Hydraulic Structure Inventory

Bighole River Hydraulic Structure Inventory

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel from bridge.

Figure 3. View of downstream channel from bridge.

Figure 4. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel from bridge.

Figure 3. View of downstream channel from bridge.

Figure 4. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel from bridge.

Figure 3. View of downstream channel from bridge.

Figure 4. View of downstream face.

BIGHOLE RIVER HYDRAULIC STRUCTURE INVENTORY

Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel from bridge.

Figure 3. View of downstream channel from bridge.

Figure 4. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of bridge at river left.

Figure 2. Upstream face of bridge at river right.

Figure 3. View of upstream channel.

Figure 4. View of downstream channel.

Figure 5. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel.

Figure 3. View of downstream channel.

Figure 4. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel.

Figure 3. View of downstream channel.

Figure 4. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel.

Figure 3. View of downstream channel.

Figure 4. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel (river left).

Figure 3. View of upstream channel (river right).

Figure 4. View of downstream channel.

Figure 5. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel.

Figure 3. View of downstream channel.

Figure 4. View of downstream face (river left).

Figure 5. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel.

Figure 3. View of downstream channel.

Figure 4. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of crossing.

Figure 2. View of upstream channel.

Figure 3. View of downstream channel.

Figure 4. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel.

Figure 3. View of downstream channel.

Figure 4. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of bridge.

Figure 2. View of upstream channel (river right).

Figure 3. View of upstream channel (river left).

Figure 4. View of downstream channel.

Figure 5. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of crossing.

Figure 2. View of upstream channel.

Figure 3. View of downstream channel.

Figure 4. View of downstream face.


Bighole River Hydraulic Structure Inventory
31
30
Anaconda
0 50 100 200
Feet

Bighole River Hydraulic Structure Inventory

Bighole River Hydraulic Structure Inventory

BIGHOLE RIVER HYDRAULIC STRUCTURE INVENTORY

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of crossing.

Figure 2. View of upstream channel.

Figure 3. View of downstream channel.

Figure 4. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of crossing.

Figure 2. View of upstream channels (river right).

Figure 3. View of upstream channels.

Figure 4. View of upstream channel (left channel).

Figure 5. View of upstream channel (left channel).

Figure 6. View of downstream channel

Figure 7. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of crossing.

Figure 2. View of upstream channel.

Figure 3. View of downstream channel.

Figure 4. View of downstream face.

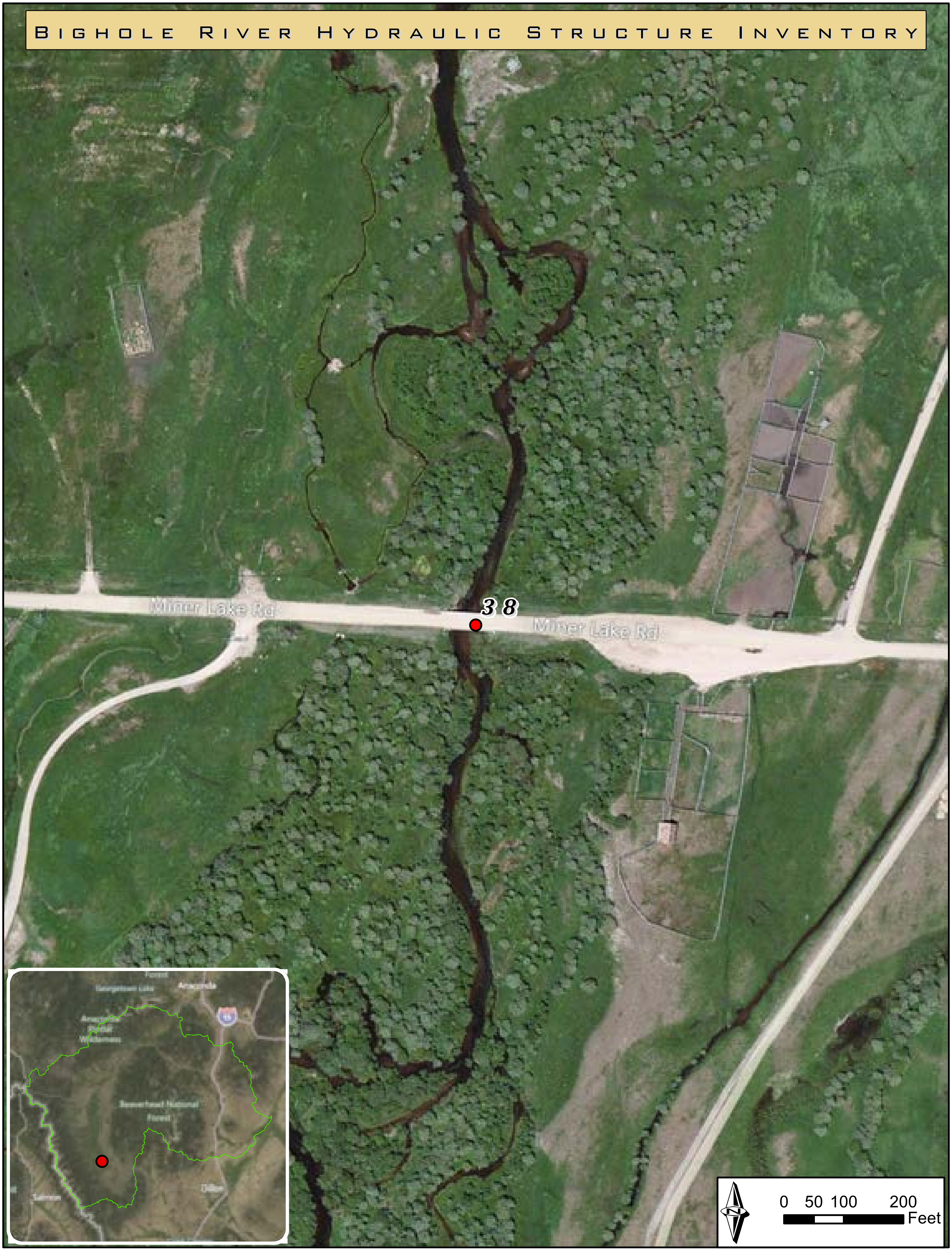
Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of crossing.

Figure 2. View of upstream channel.

Figure 3. View of downstream channel.

Figure 4. View of downstream face.



Bighole River Hydraulic Structure Inventory
Miner Lake Rd
3 8
Miner Lake Rd
Anaconda
Beaverhead National Forest
Dillon
0 50 100 200
Feet

Figure 1. Upstream face of crossing (river left).

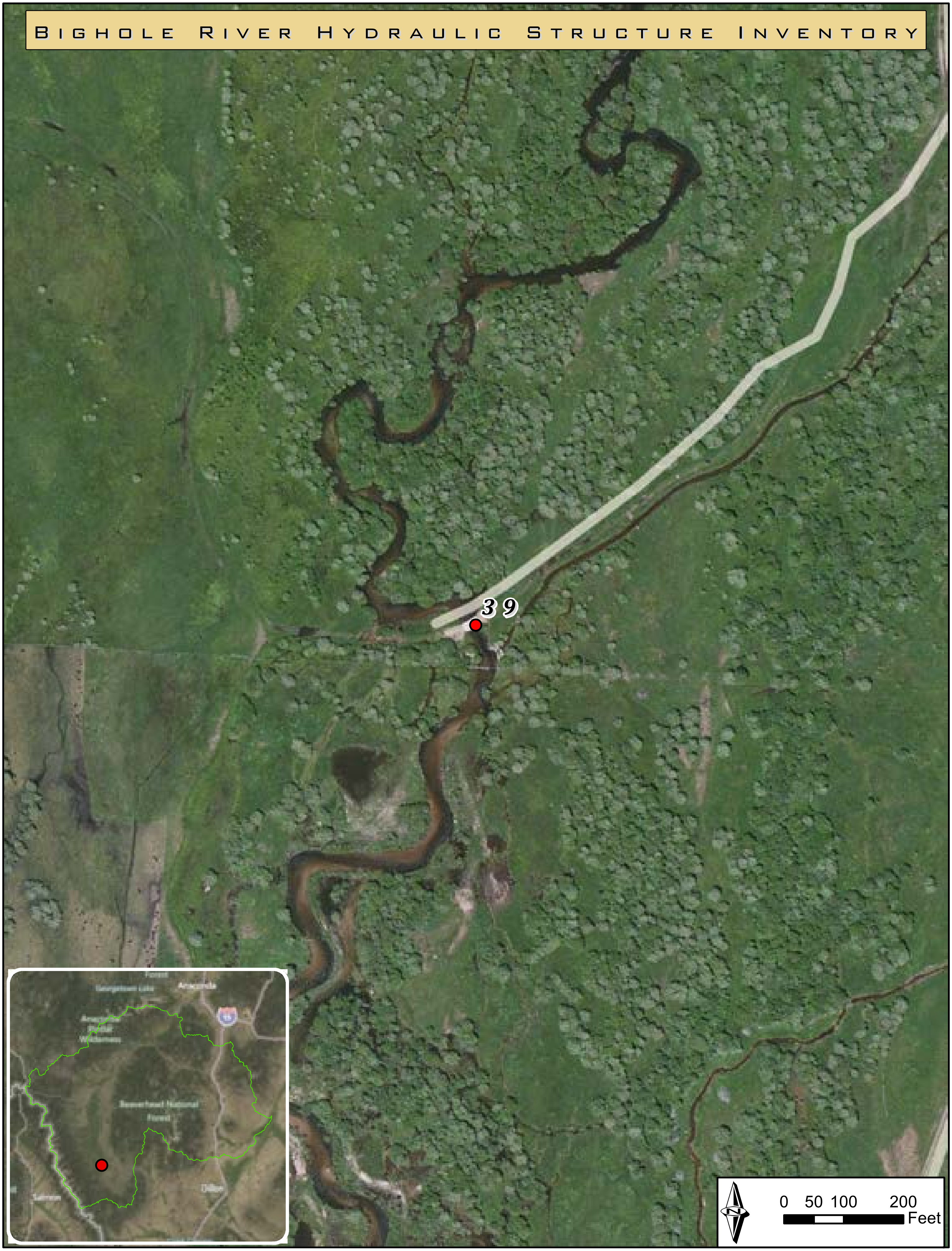
Figure 2. View of upstream face (river right).

Figure 3. View of upstream channel.

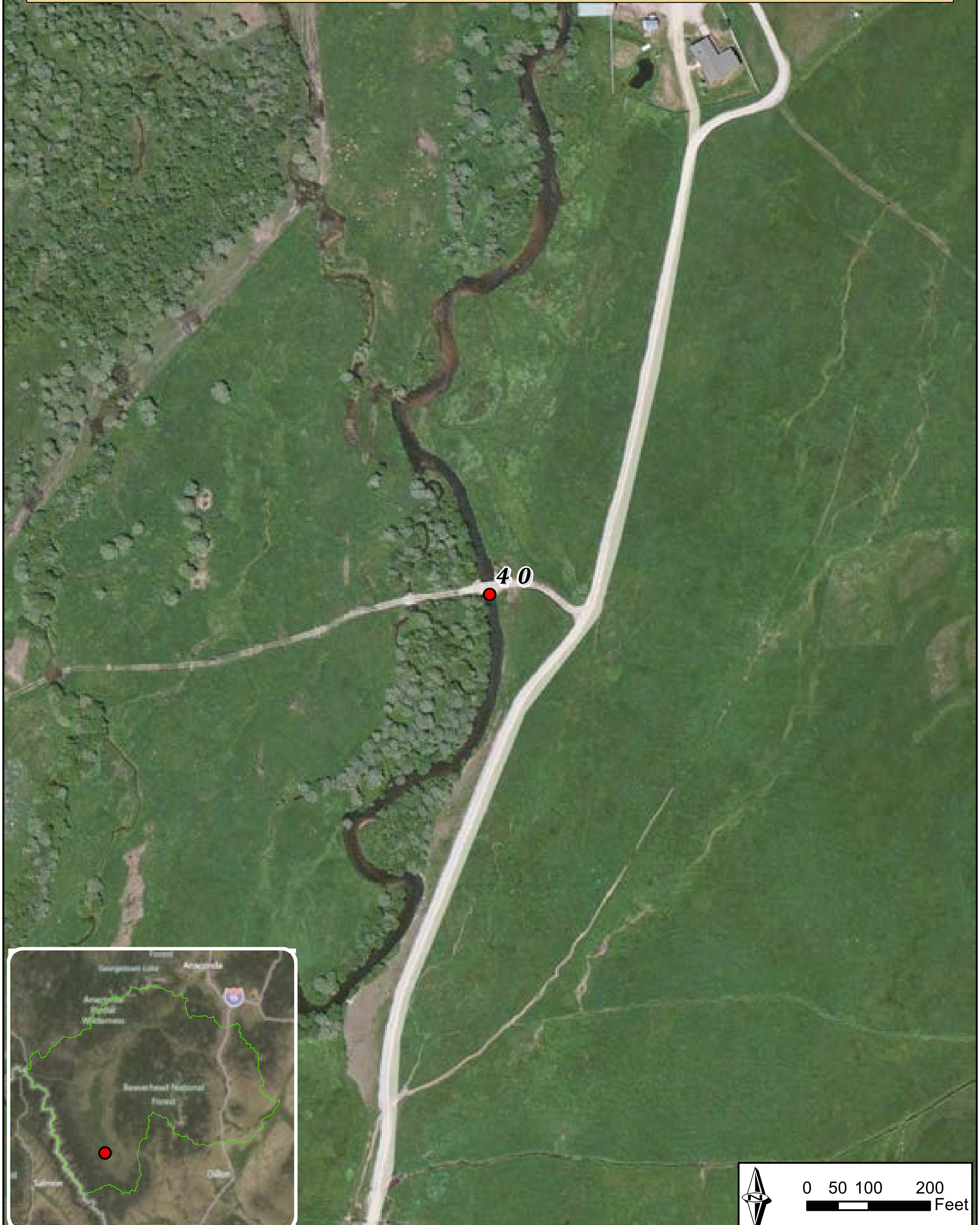
Figure 4. View of downstream channel.

Figure 5. View of downstream face (river left).

Figure 6. View of downstream face (river right).


Bighole River Hydraulic Structure Inventory
39
0 50 100 200
Feet

Bighole River Hydraulic Structure Inventory



Bighole River Hydraulic Structure Inventory

BIGHOLE RIVER HYDRAULIC STRUCTURE INVENTORY

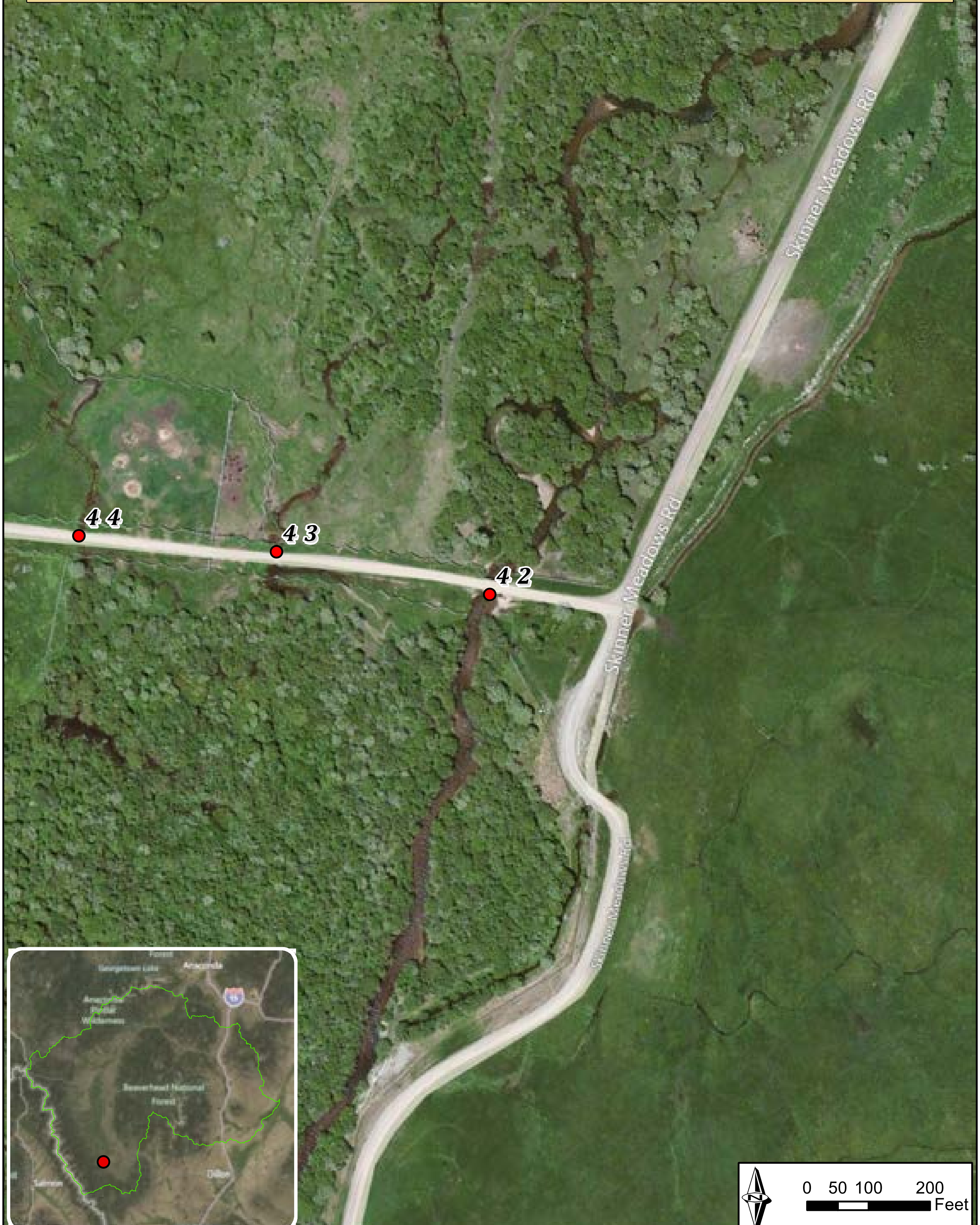


Figure 1. Upstream face of crossing.

Figure 2. View of left overbank.

Figure 3. View of upstream channel.

Figure 4. View of downstream channel.

Figure 5. View of downstream face (river left).

Bighole River Hydraulic Structure Inventory

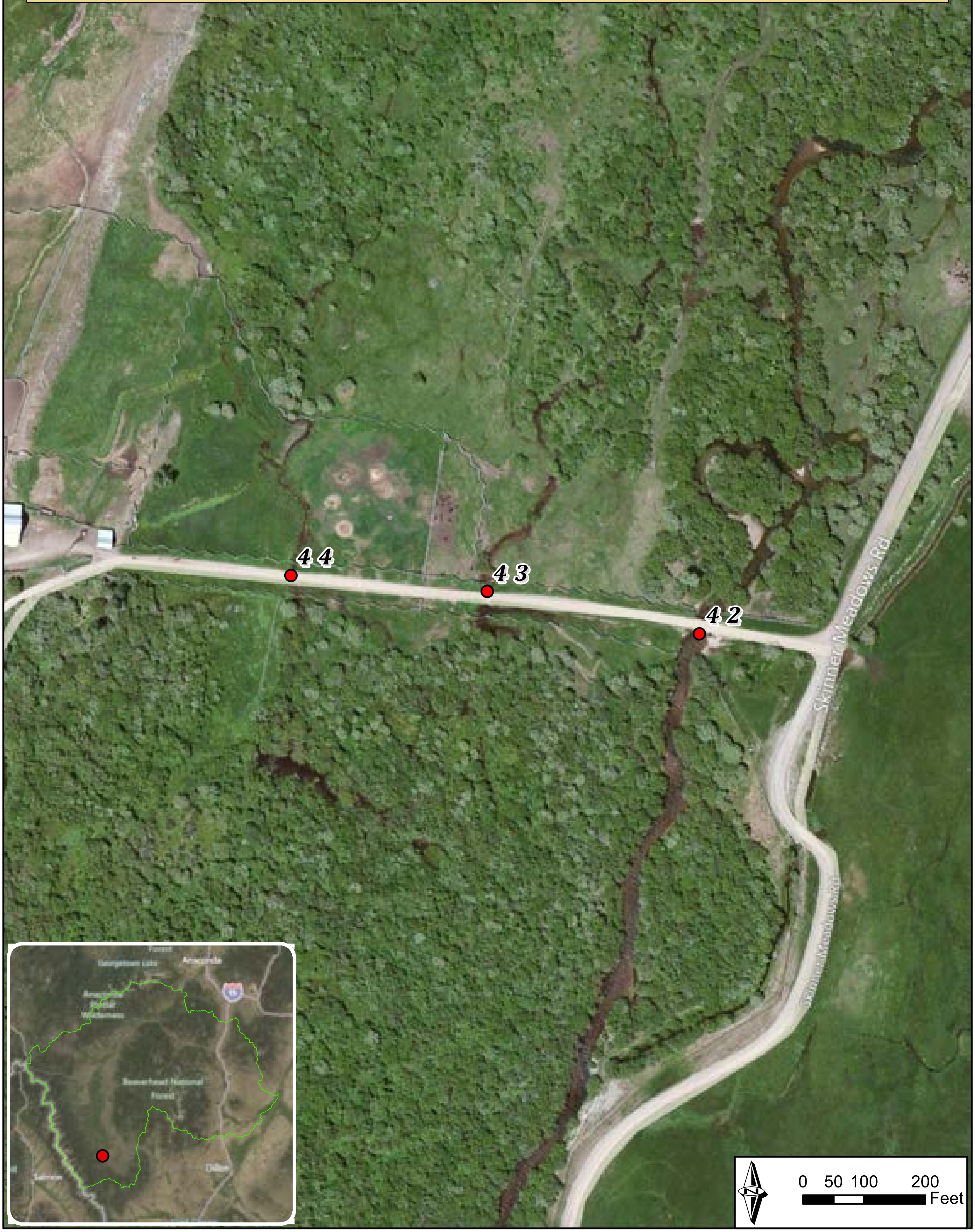


Figure 1. Upstream face of crossing.

Figure 2. View of upstream channel.

Figure 3. View of downstream channel.

Figure 4. View of downstream face.

Figure 5. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of crossing.

Figure 2. View of upstream right overbank

Figure 3. View of upstream channel.

Figure 4. View of downstream channel.

Figure 5. View of downstream face.

Bighole River Hydraulic Structure Inventory

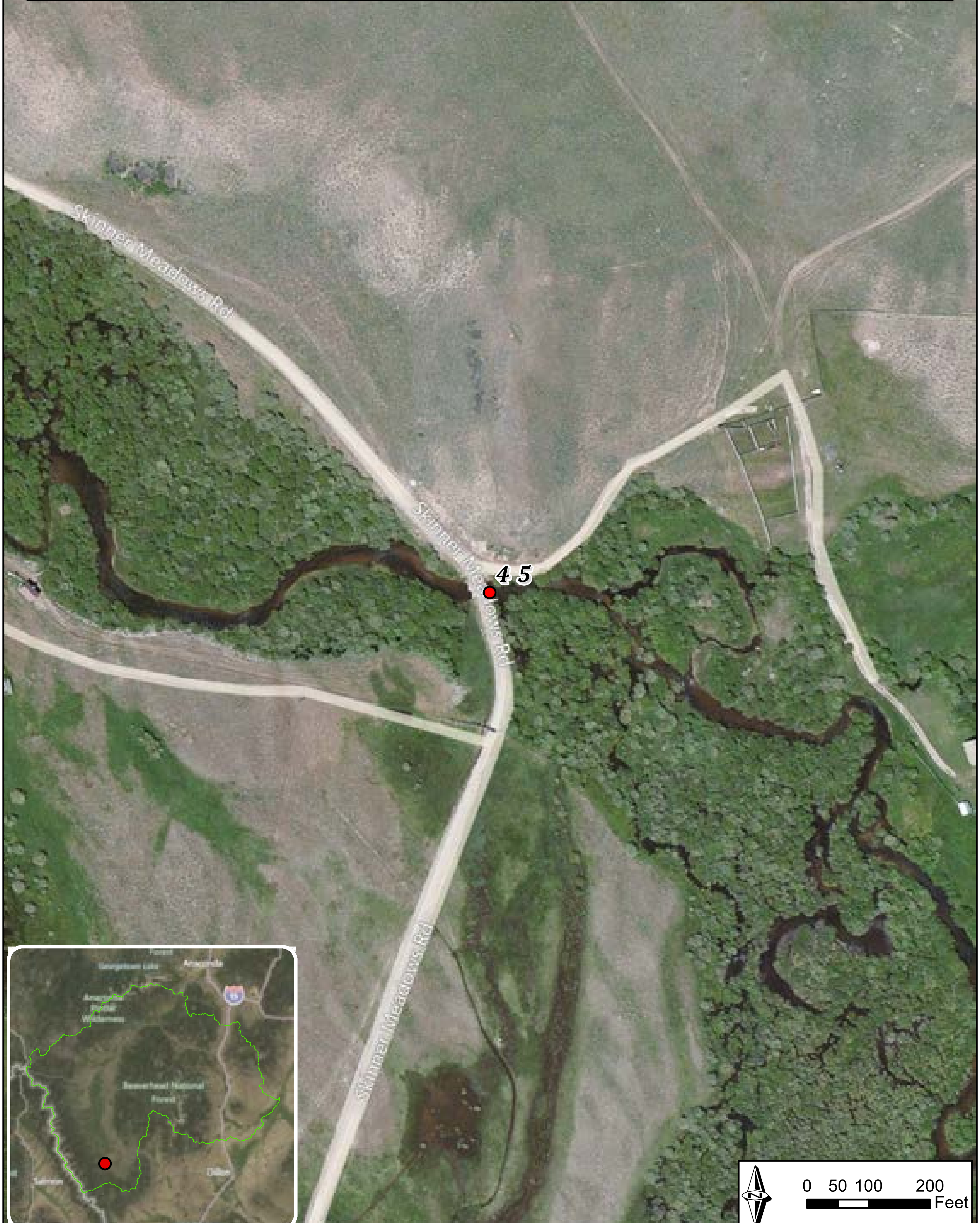


Figure 1. Upstream face of crossing.

Figure 2. View of upstream face from river right.

Figure 3. View of upstream channel.

Figure 4. View of downstream channel.

Figure 5. View of downstream face.

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of crossing.

Figure 2. View of crossing and right overbank from left overbank.

Figure 3. View of upstream channel.

Figure 4. View of downstream channel.

Figure 5. View of downstream face.

Figure 6. View of downstream face (river left).

Figure 7. View of downstream face (river right).

Bighole River Hydraulic Structure Inventory

Figure 1. Upstream face of crossing.

Figure 2. View of crossing from left overbank.

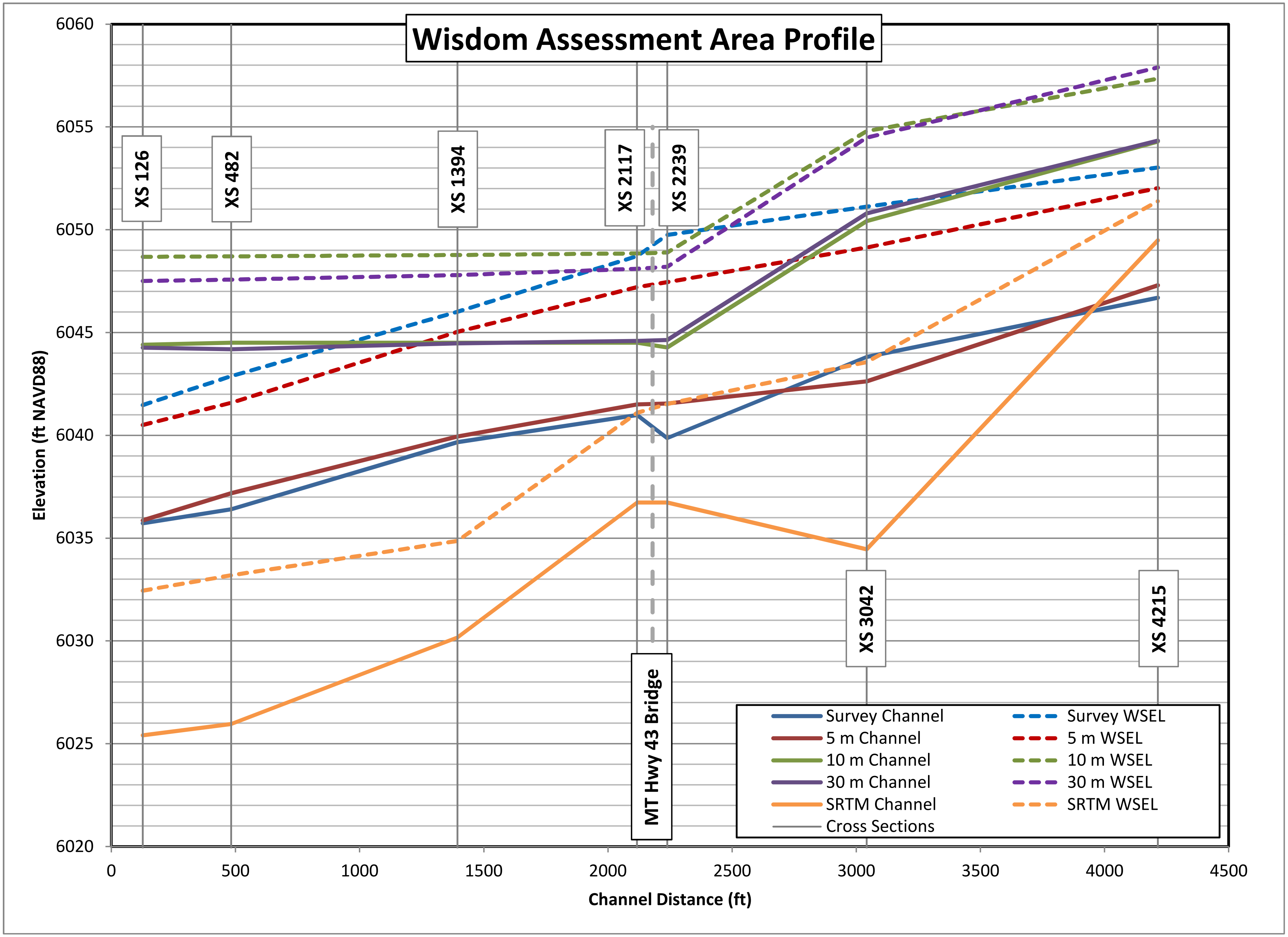
Figure 3. View of upstream channel.

Figure 4. View of downstream channel.

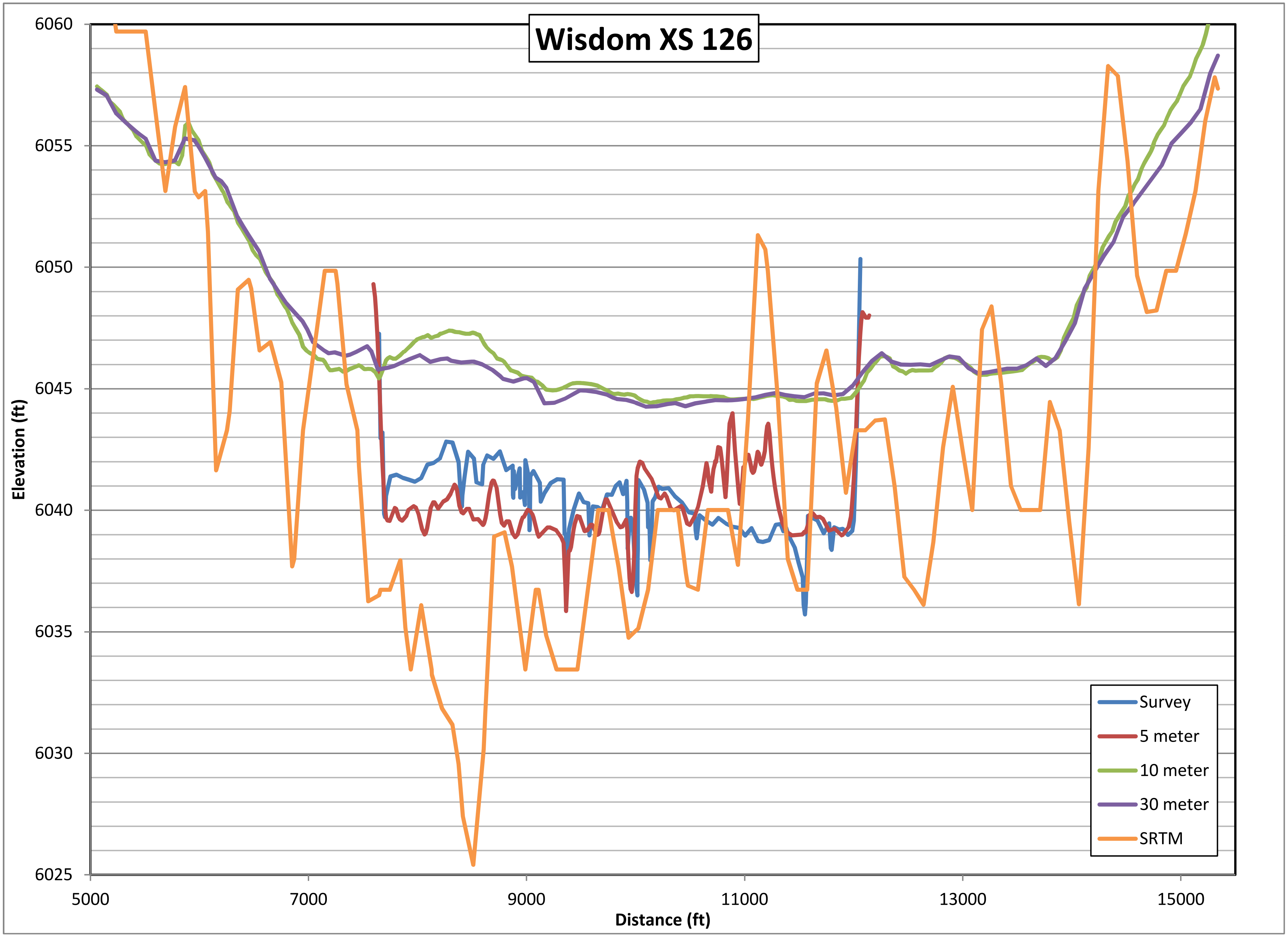
Figure 5. View of downstream face.

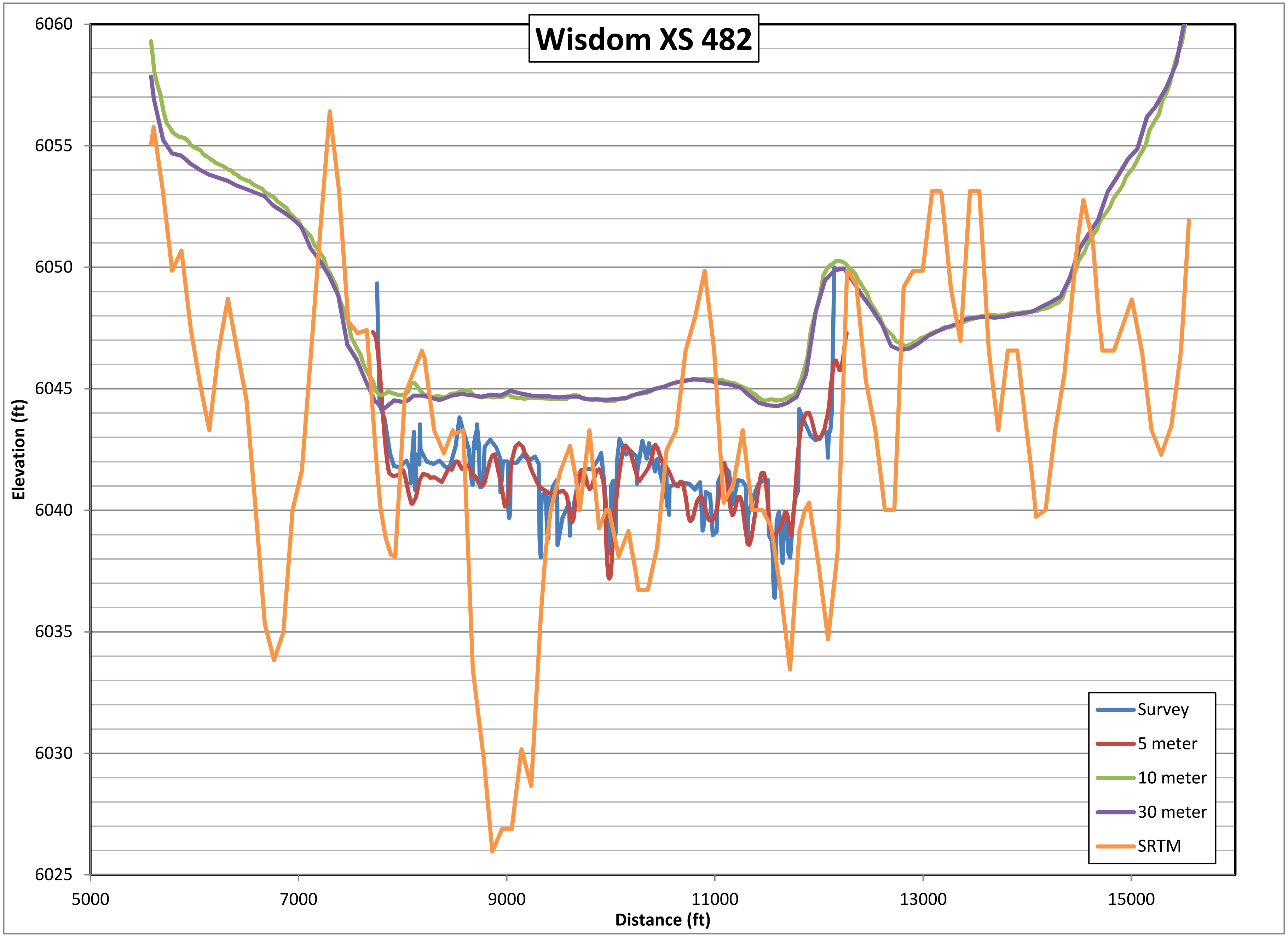
Bighole River Hydraulic Structure Inventory

Appendix B. Wisdom Reach Comparisons

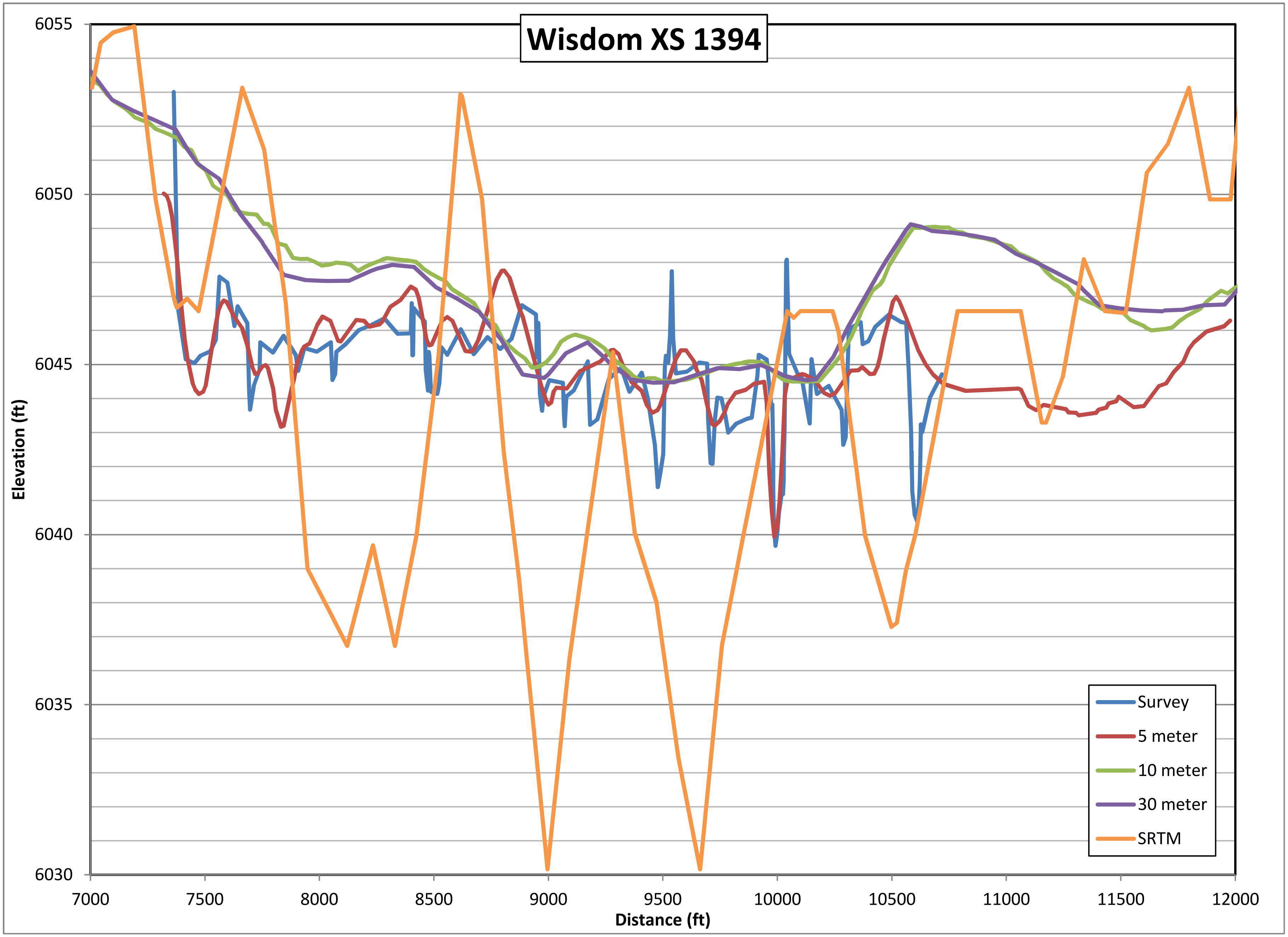


Wisdom Assessment Area Profile
XS 126
XS 482
XS 1394
XS 2117
XS 2239
XS 3042
XS 4215
MT Hwy 43 Bridge
Elevation (ft NAVD88)
6060
6055
6050
6045
6040
6035
6030
6025
6020
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Channel Distance (ft)
Survey Channel
5 m Channel
10 m Channel
30 m Channel
SRTM Channel
Cross Sections
Survey WSEL
5 m WSEL
10 m WSEL
30 m WSEL
SRTM WSEL

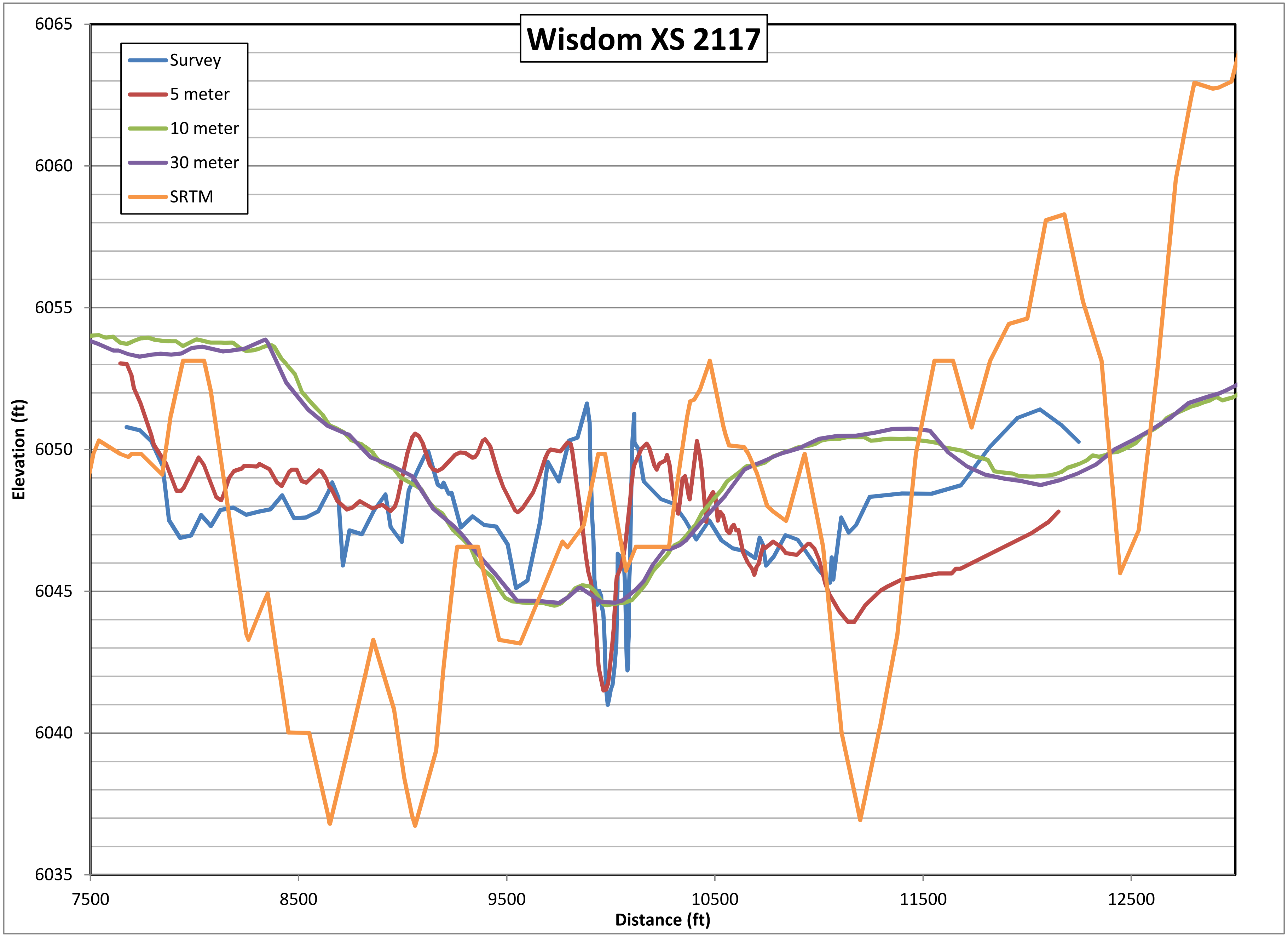

Wisdom XS 126
Elevation (ft)
Distance (ft)
6060
6055
6050
6045
6040
6035
6030
6025
5000
7000
9000
11000
13000
15000
Survey
5 meter
10 meter
30 meter
SRTM

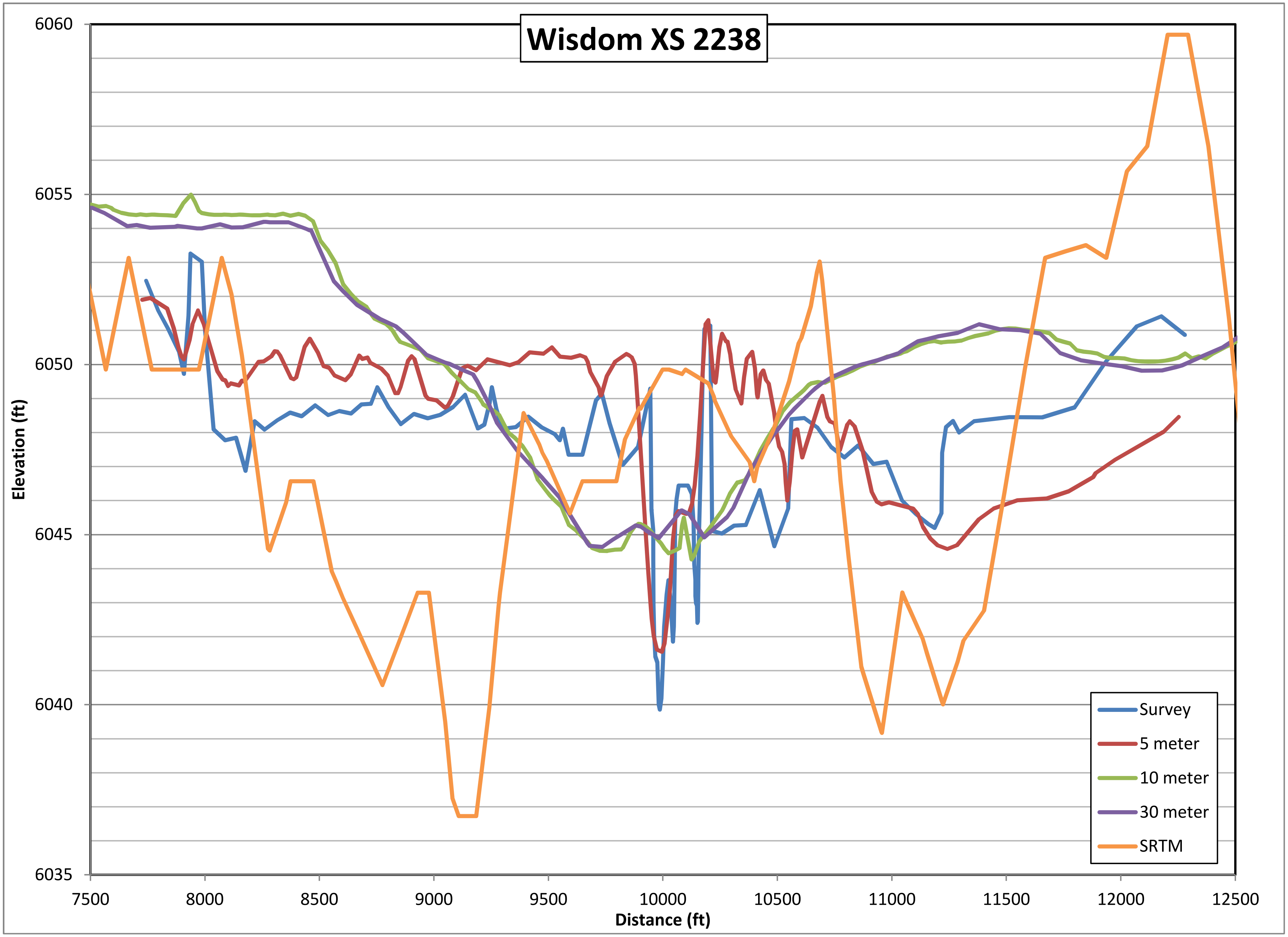


Wisdom XS 482
6060
6055
6050
6045
6040
6035
6030
6025
Elevation (ft)
5000
7000
9000
11000
13000
15000
Distance (ft)
Survey
5 meter
10 meter
30 meter
SRTM

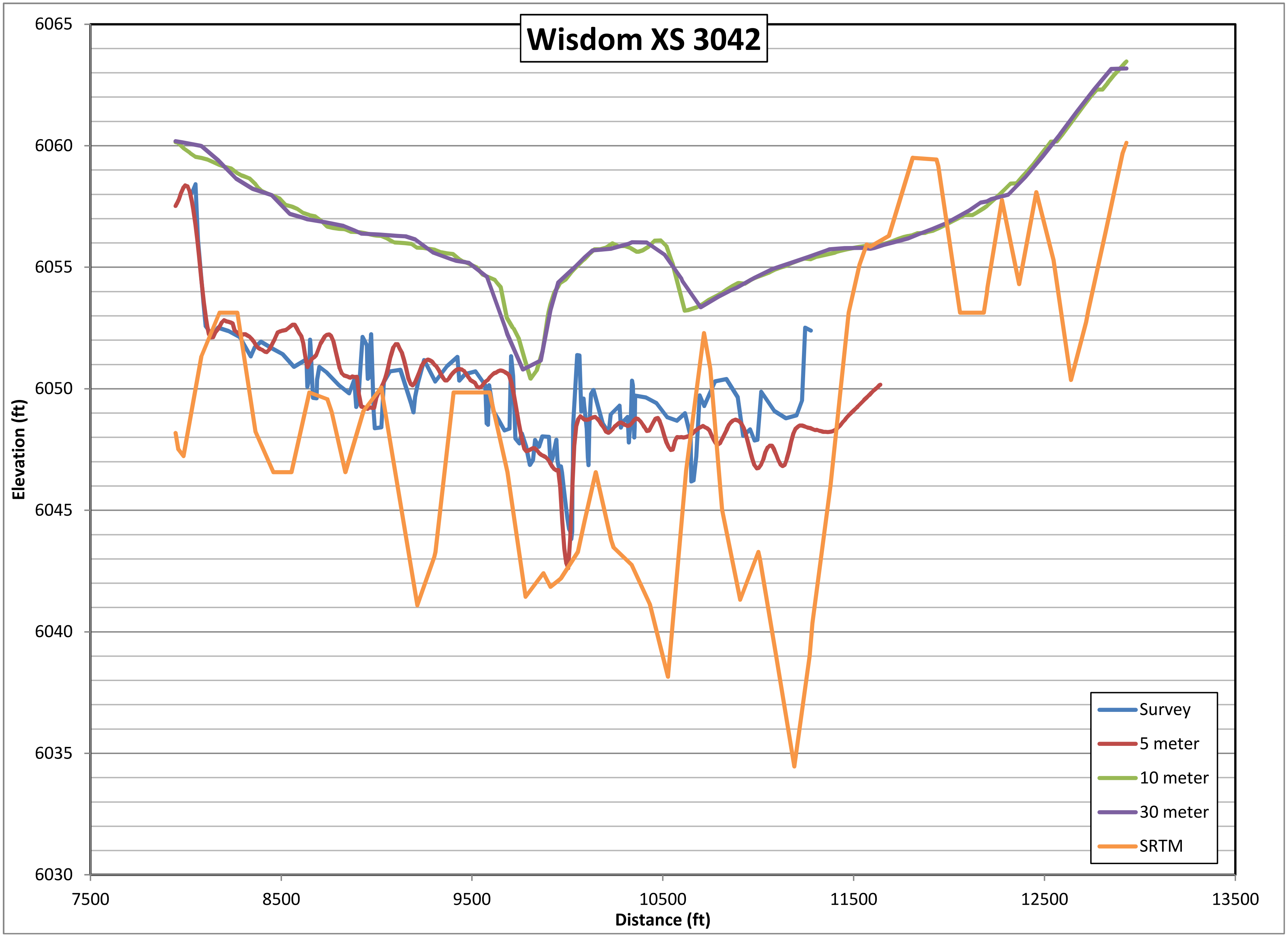


Wisdom XS 1394
6055
6050
6045
6040
6035
6030
Elevation (ft)
7000
7500
8000
8500
9000
9500
10000
10500
11000
11500
12000
Distance (ft)
Survey
5 meter
10 meter
30 meter
SRTM

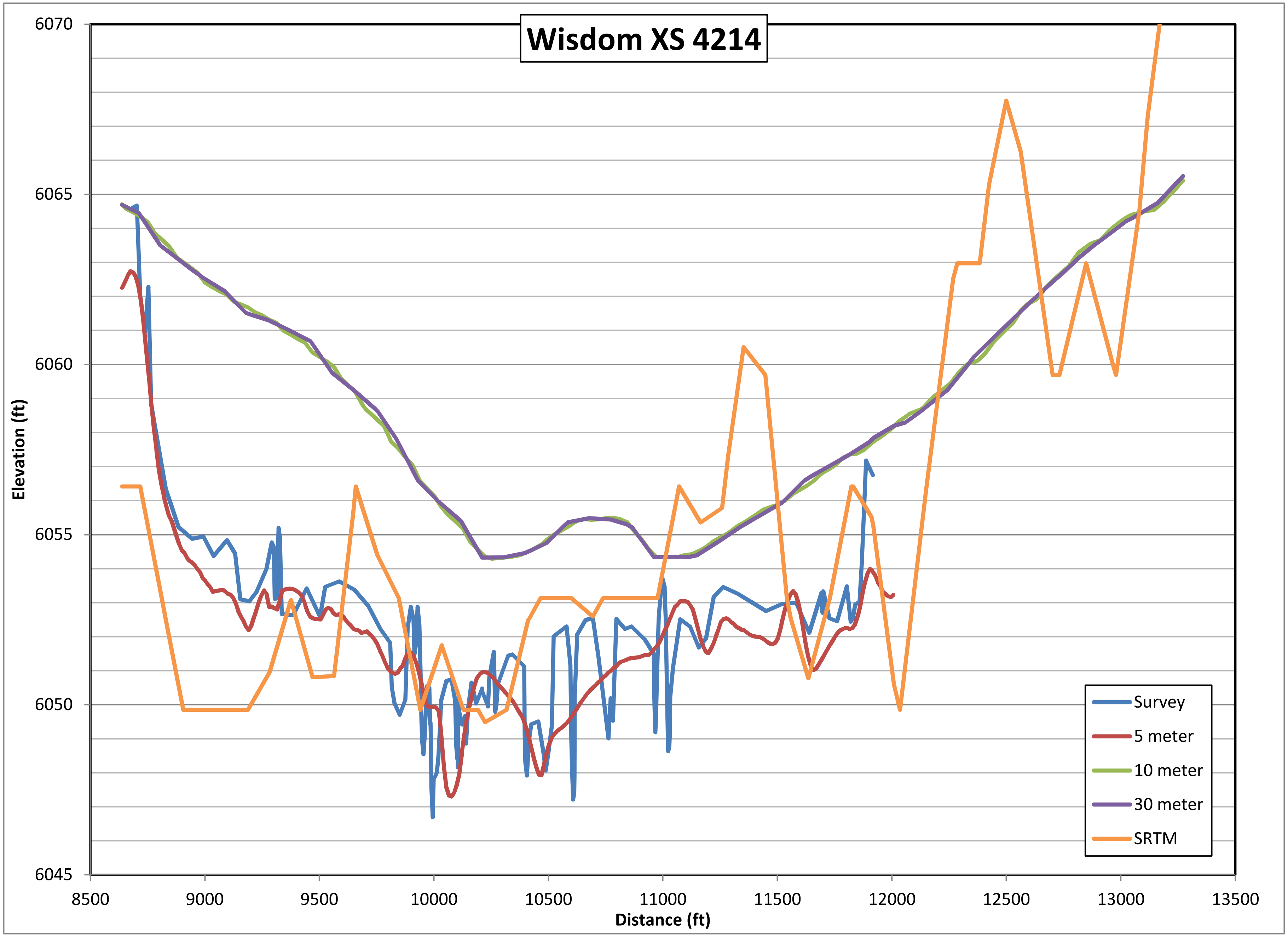

Wisdom XS 2117
Survey
5 meter
10 meter
30 meter
SRTM
6065
6060
6055
6050
6045
6040
6035
Elevation (ft)
7500
8500
9500
10500
11500
12500
Distance (ft)



Wisdom XS 2238
Elevation (ft)
Distance (ft)
6060
6055
6050
6045
6040
6035
7500
8000
8500
9000
9500
10000
10500
11000
11500
12000
12500
Survey
5 meter
10 meter
30 meter
SRTM

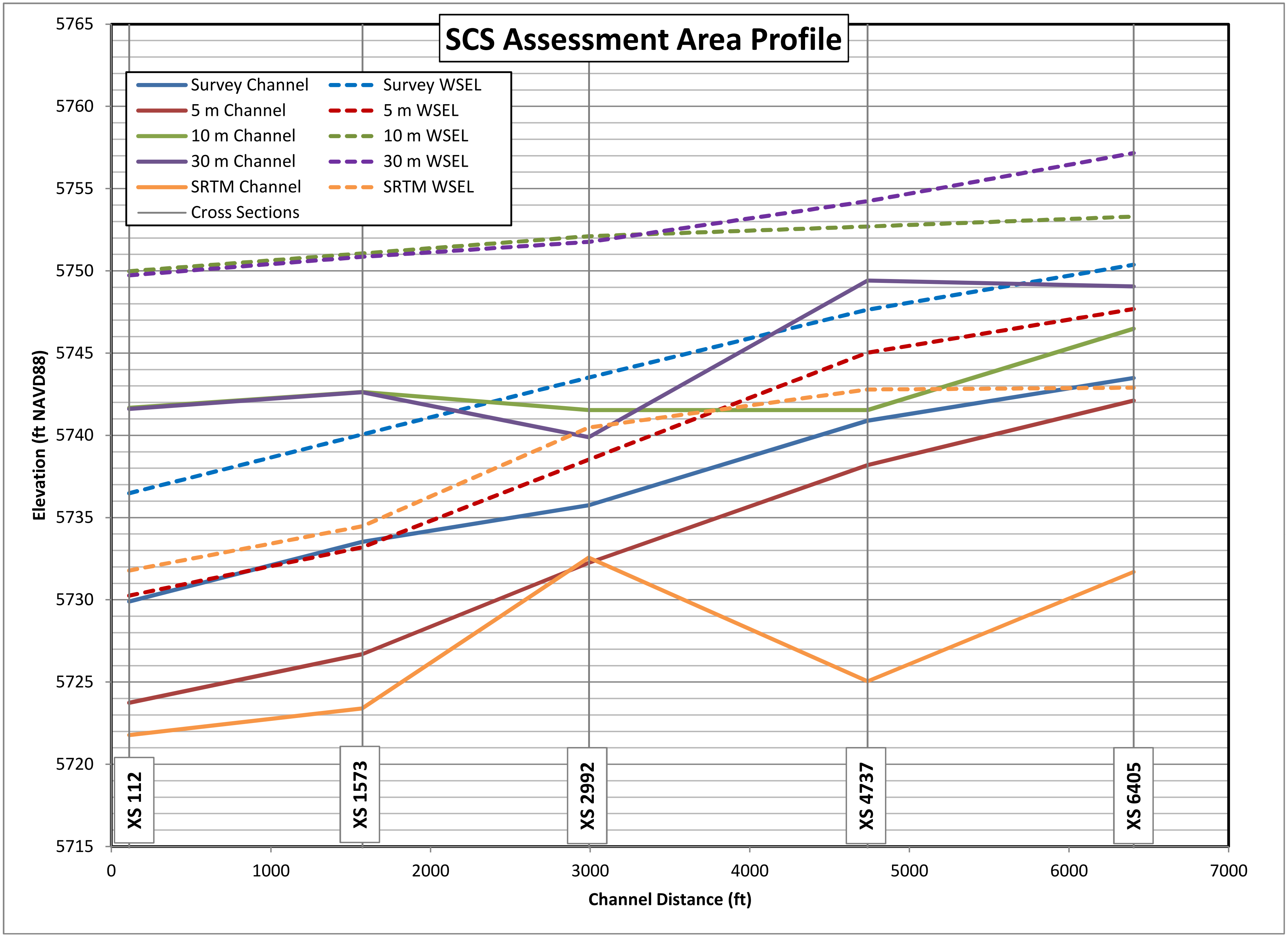


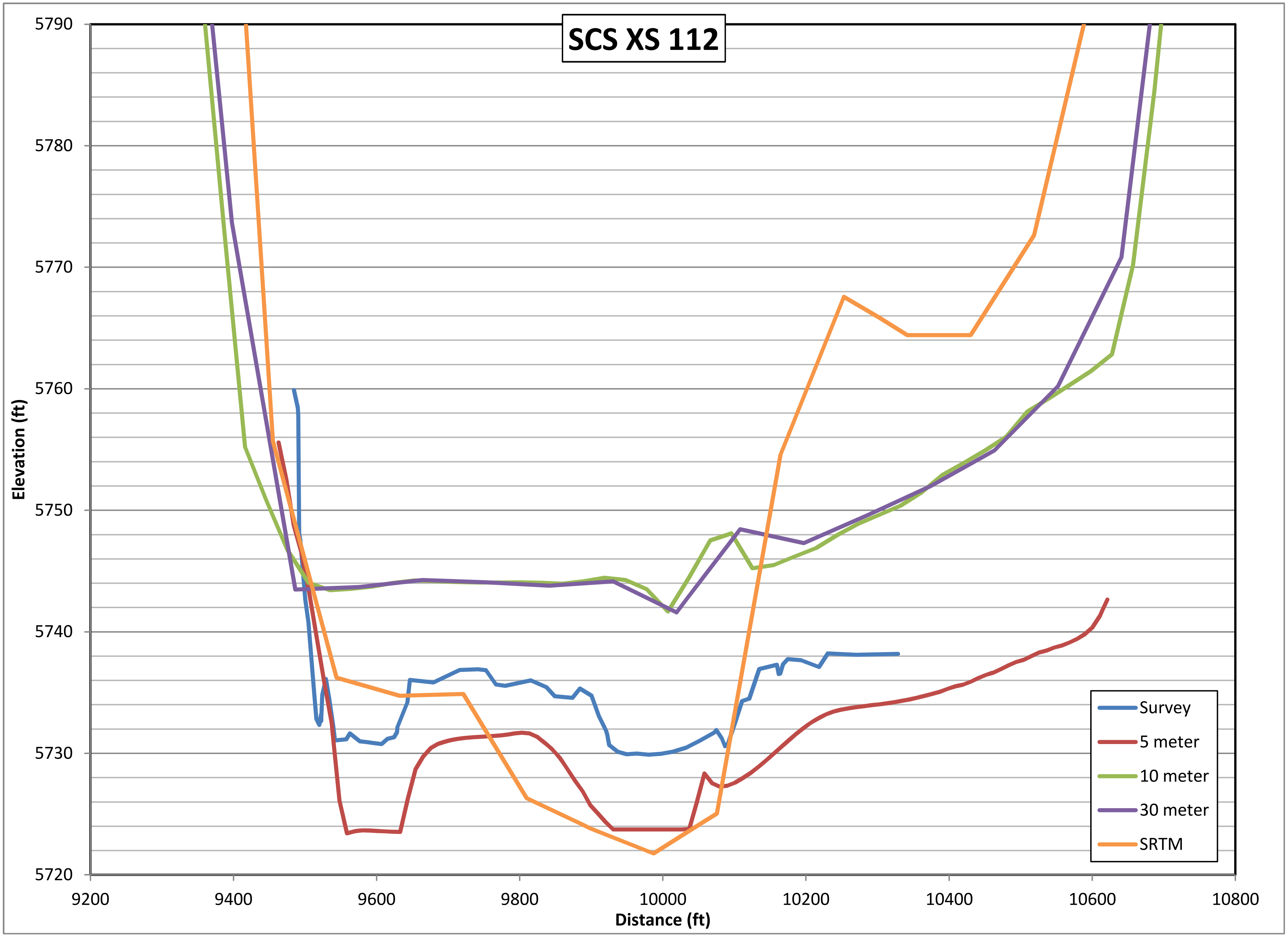
Wisdom XS 3042
Elevation (ft)
6065
6060
6055
6050
6045
6040
6035
6030
7500
8500
9500
10500
11500
12500
13500
Distance (ft)
Survey
5 meter
10 meter
30 meter
SRTM



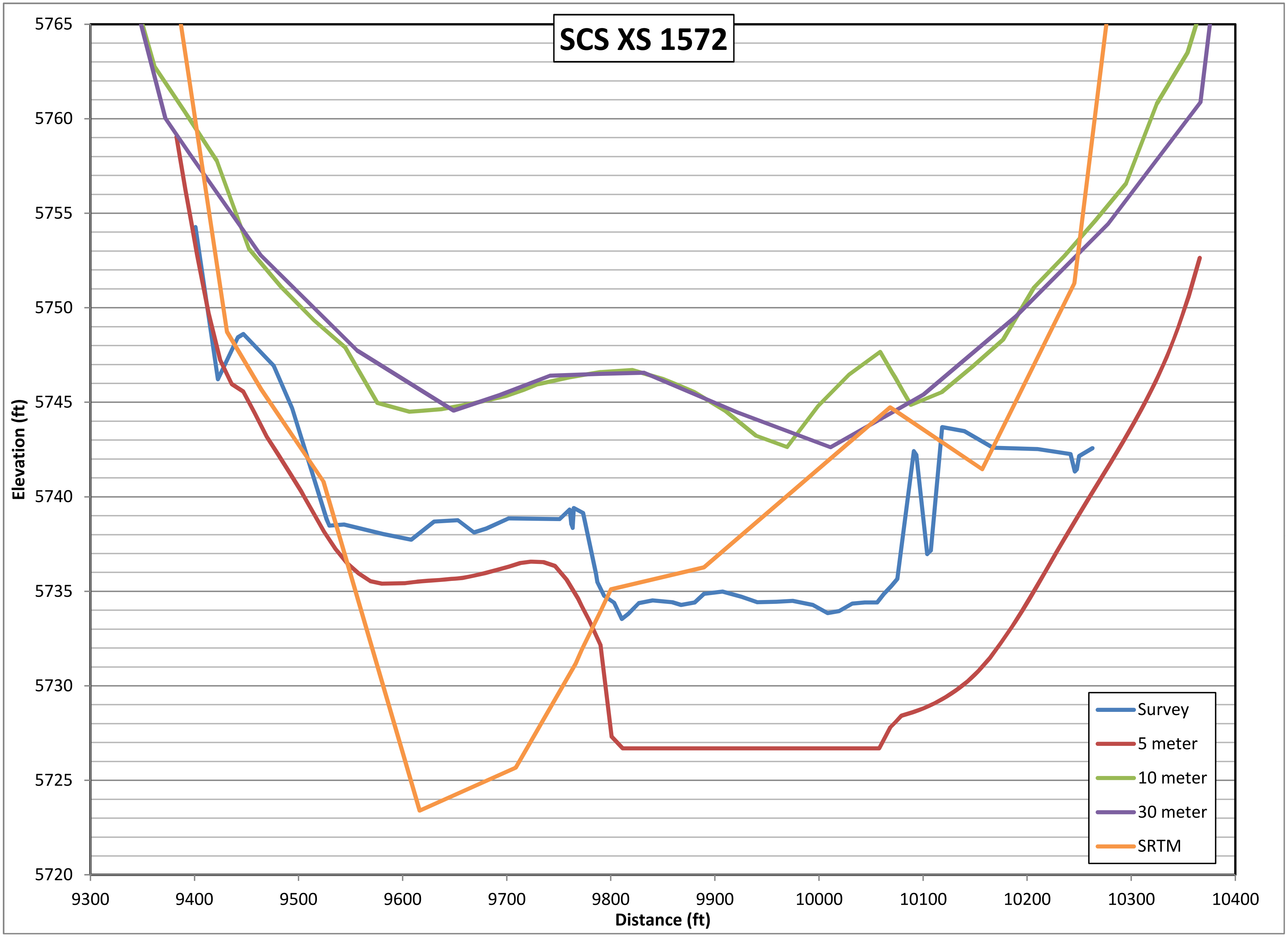
Wisdom XS 4214
Elevation (ft)
Distance (ft)
6070
6065
6060
6055
6050
6045
8500
9000
9500
10000
10500
11000
11500
12000
12500
13000
13500
Survey
5 meter
10 meter
30 meter
SRTM

Appendix C. SCS Reach Comparisons

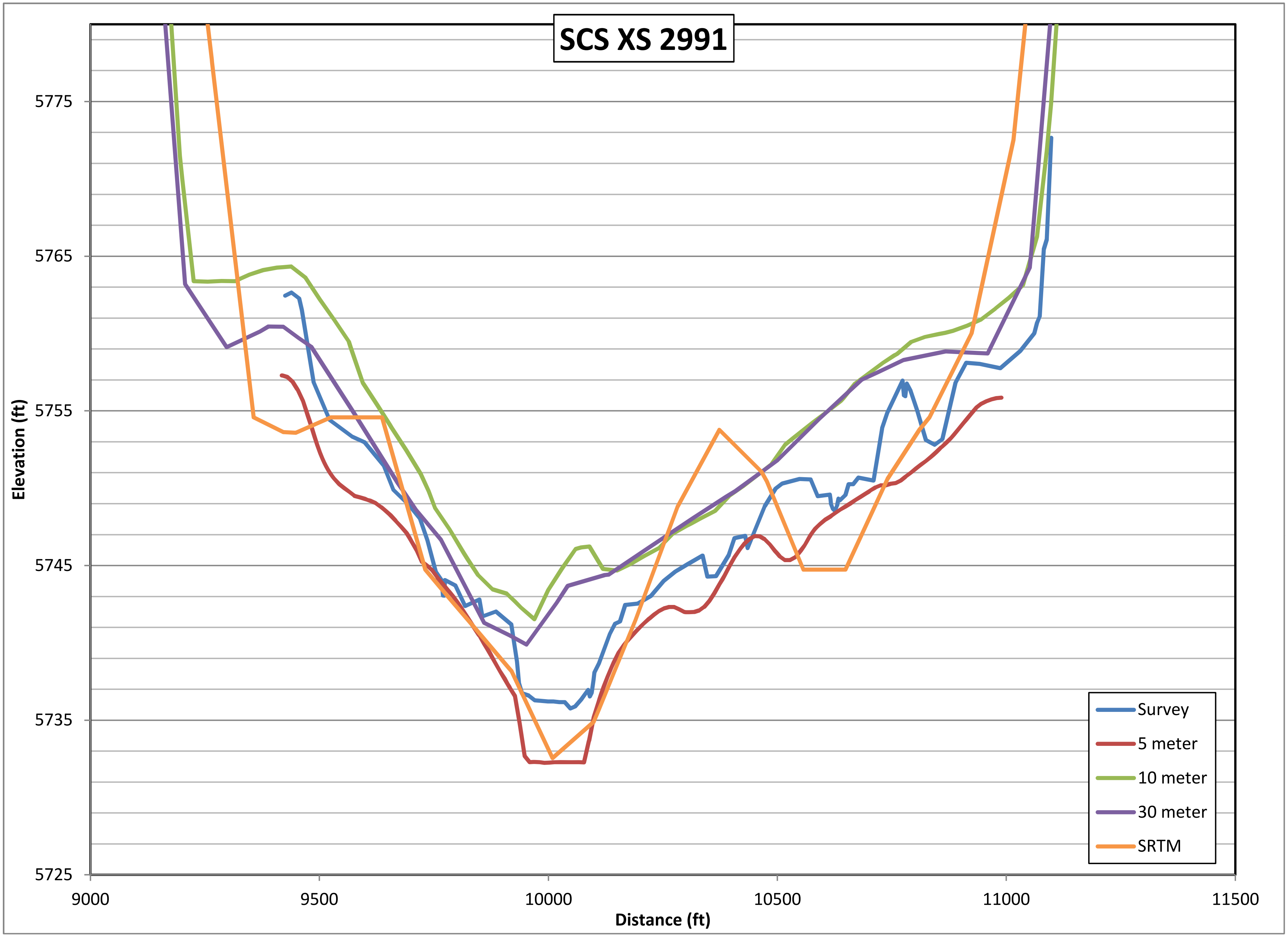

SCS Assessment Area Profile
Survey Channel
5 m Channel
10 m Channel
30 m Channel
SRTM Channel
Cross Sections
Survey WSEL
5 m WSEL
10 m WSEL
30 m WSEL
SRTM WSEL
Elevation (ft NAVD88)
5765
5760
5755
5750
5745
5740
5735
5730
5725
5720
5715
XS 112
XS 1573
XS 2992
XS 4737
XS 6405
0
1000
2000
3000
4000
5000
6000
7000
Channel Distance (ft)



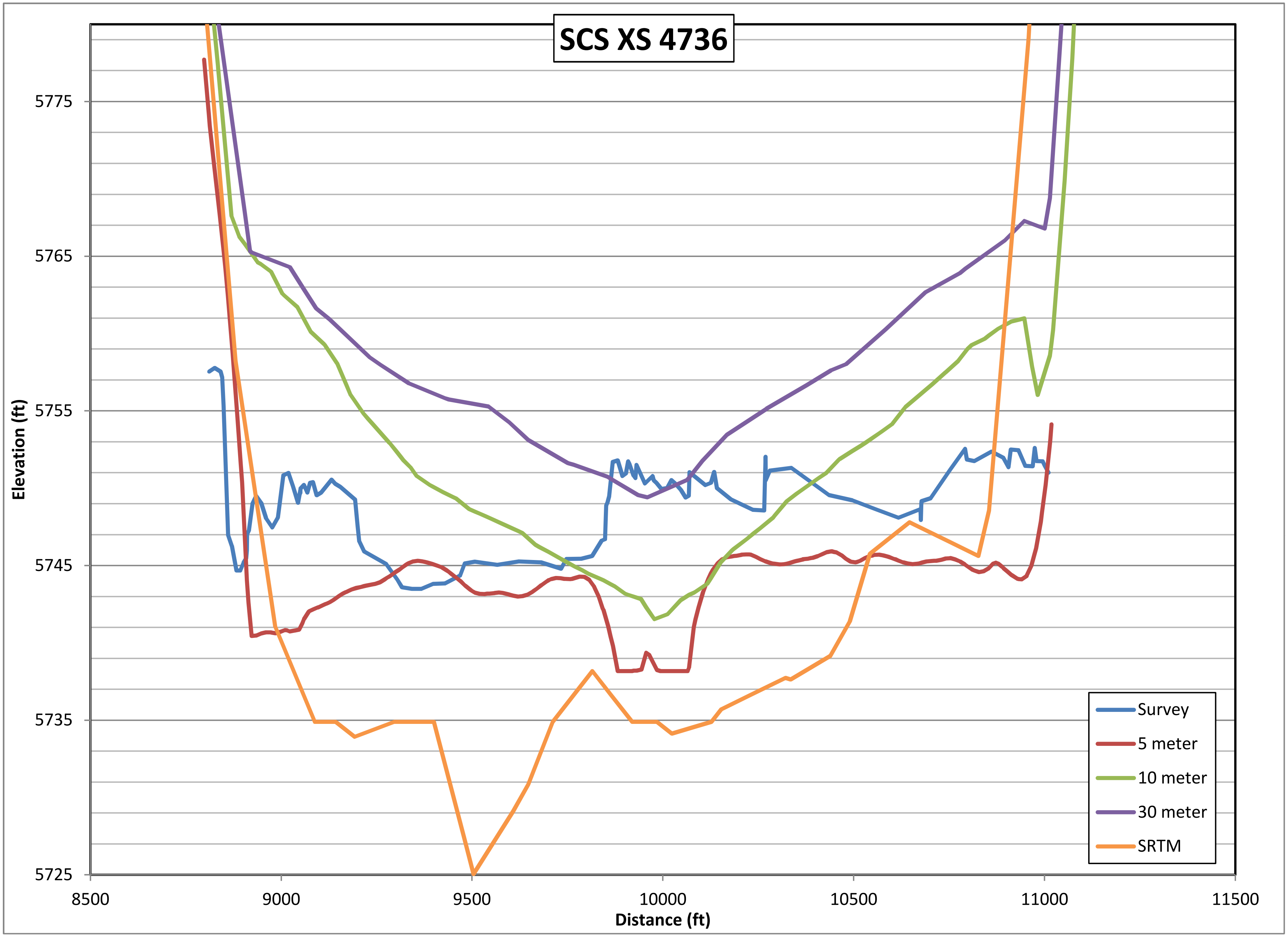
SCS XS 112
Elevation (ft)
Distance (ft)
5790
5780
5770
5760
5750
5740
5730
5720
9200
9400
9600
9800
10000
10200
10400
10600
10800
Survey
5 meter
10 meter
30 meter
SRTM



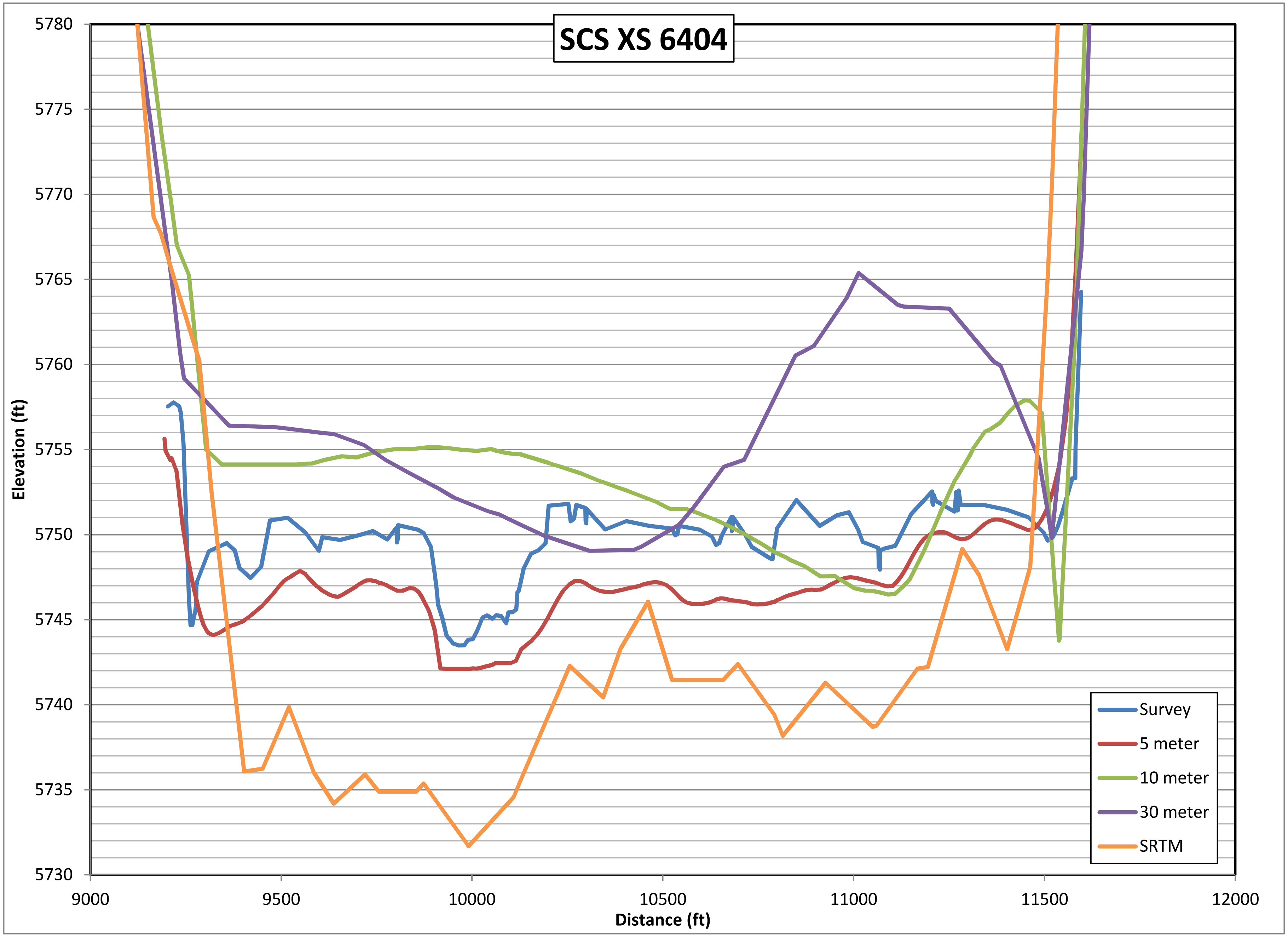
SCS XS 1572
Elevation (ft)
5765
5760
5755
5750
5745
5740
5735
5730
5725
5720
9300
9400
9500
9600
9700
9800
9900
10000
10100
10200
10300
10400
Distance (ft)
Survey
5 meter
10 meter
30 meter
SRTM



SCS XS 2991
Elevation (ft)
5775
5765
5755
5745
5735
5725
9000
9500
10000
10500
11000
11500
Distance (ft)
Survey
5 meter
10 meter
30 meter
SRTM

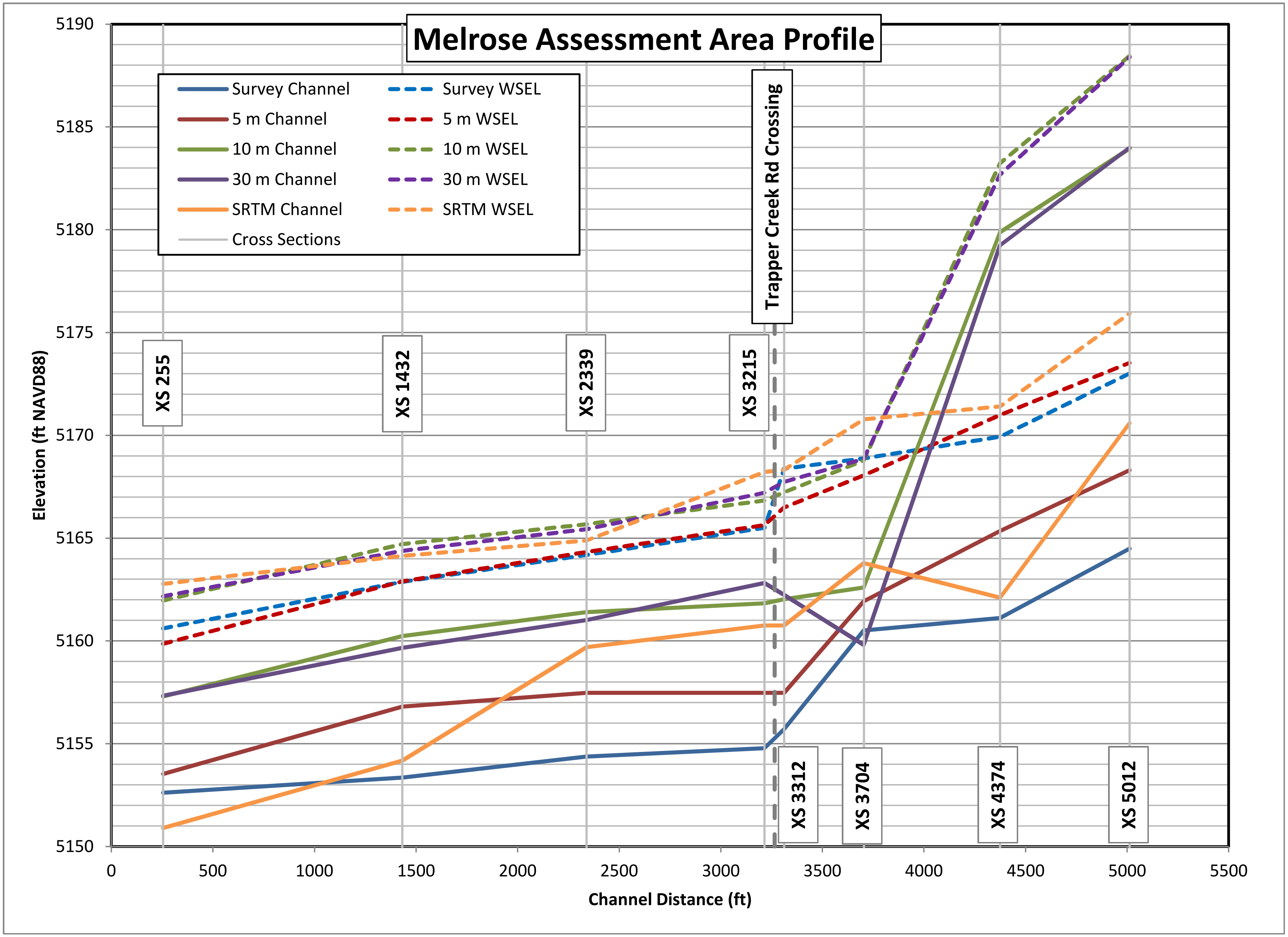


SCS XS 4736
Elevation (ft)
5775
5765
5755
5745
5735
5725
8500
9000
9500
10000
10500
11000
11500
Distance (ft)
Survey
5 meter
10 meter
30 meter
SRTM

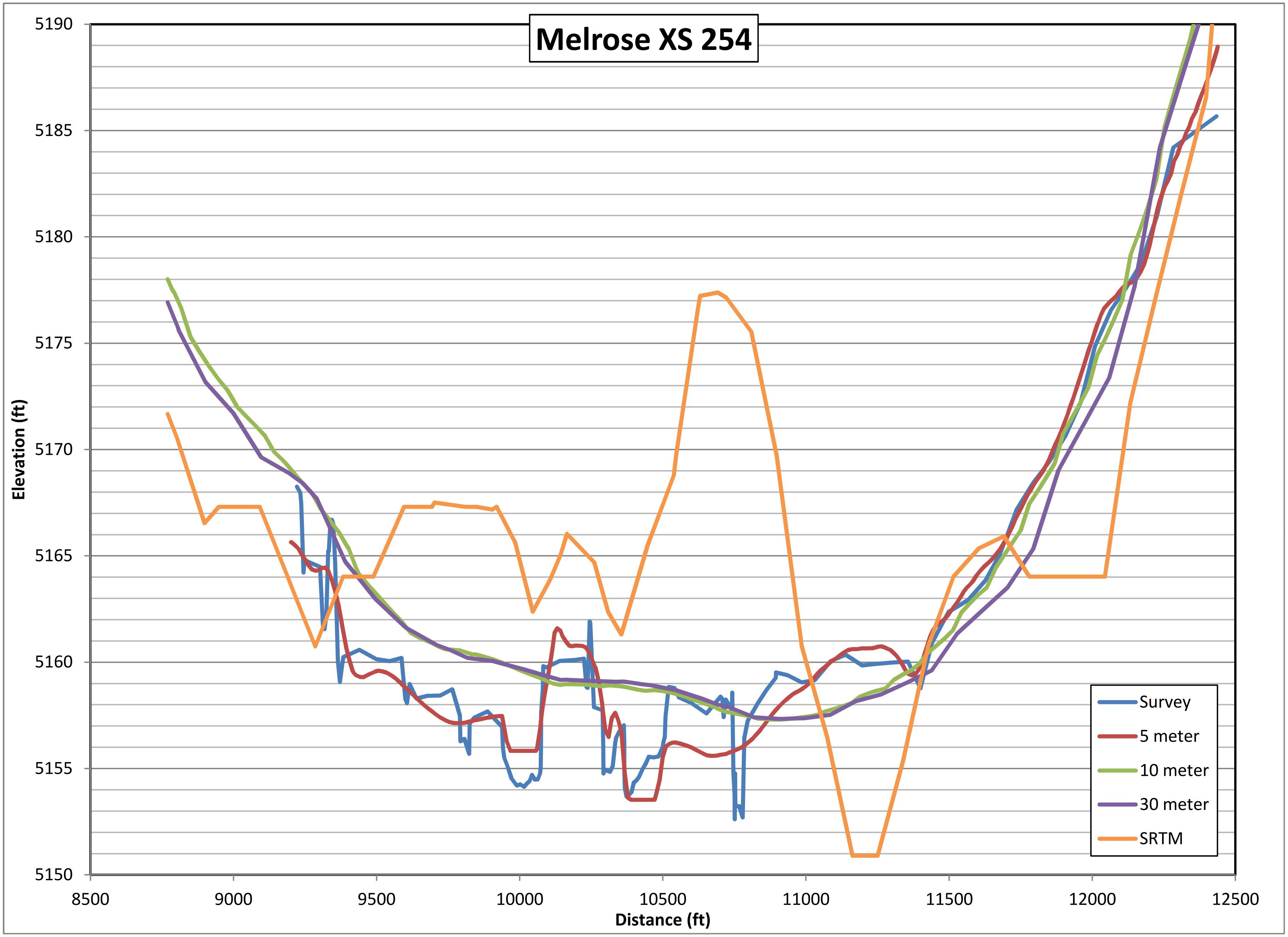


SCS XS 6404
Elevation (ft)
Distance (ft)
5780
5775
5770
5765
5760
5755
5750
5745
5740
5735
5730
9000
9500
10000
10500
11000
11500
12000
Survey
5 meter
10 meter
30 meter
SRTM

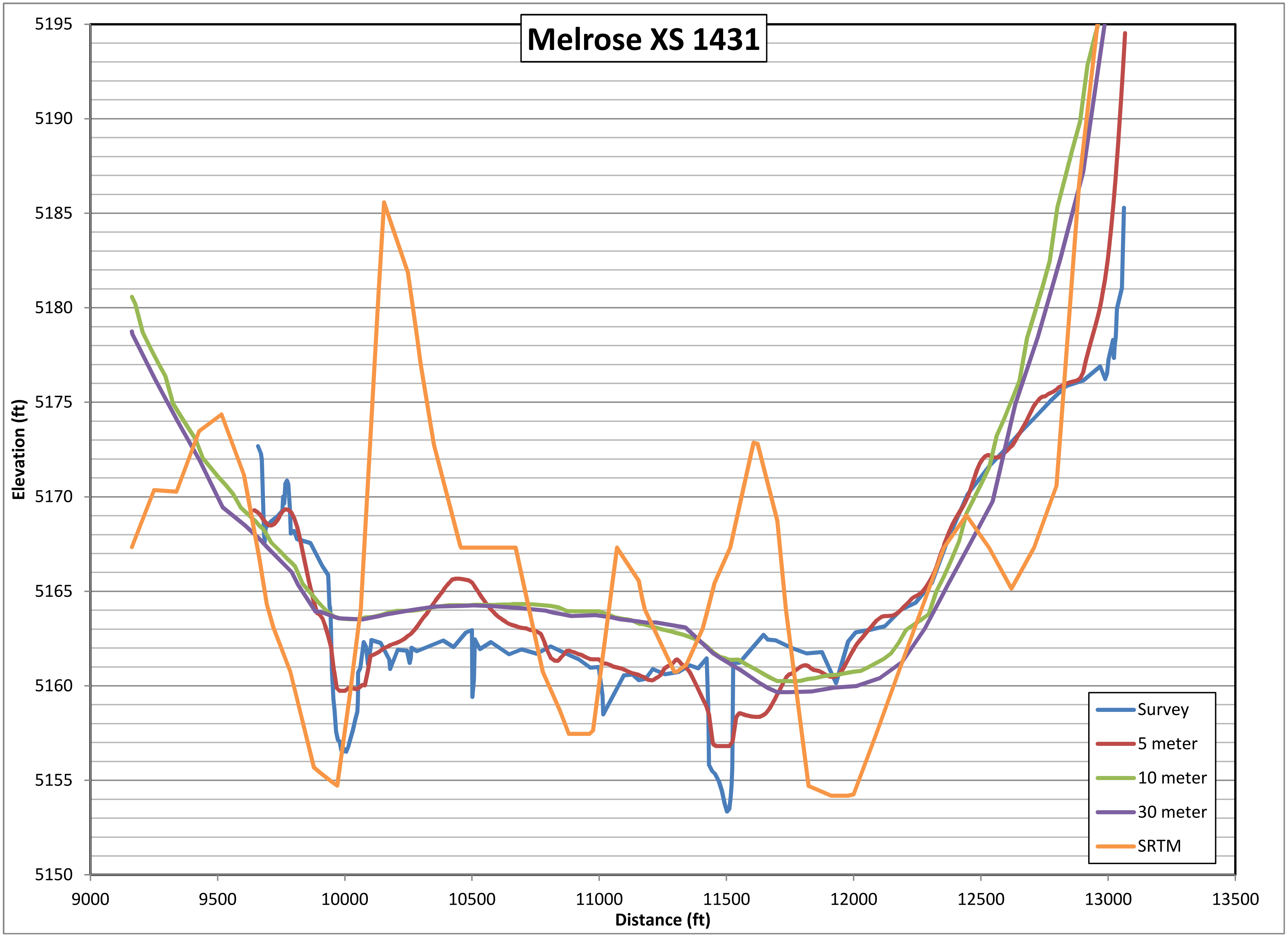
Appendix D. Melrose Reach Comparisons



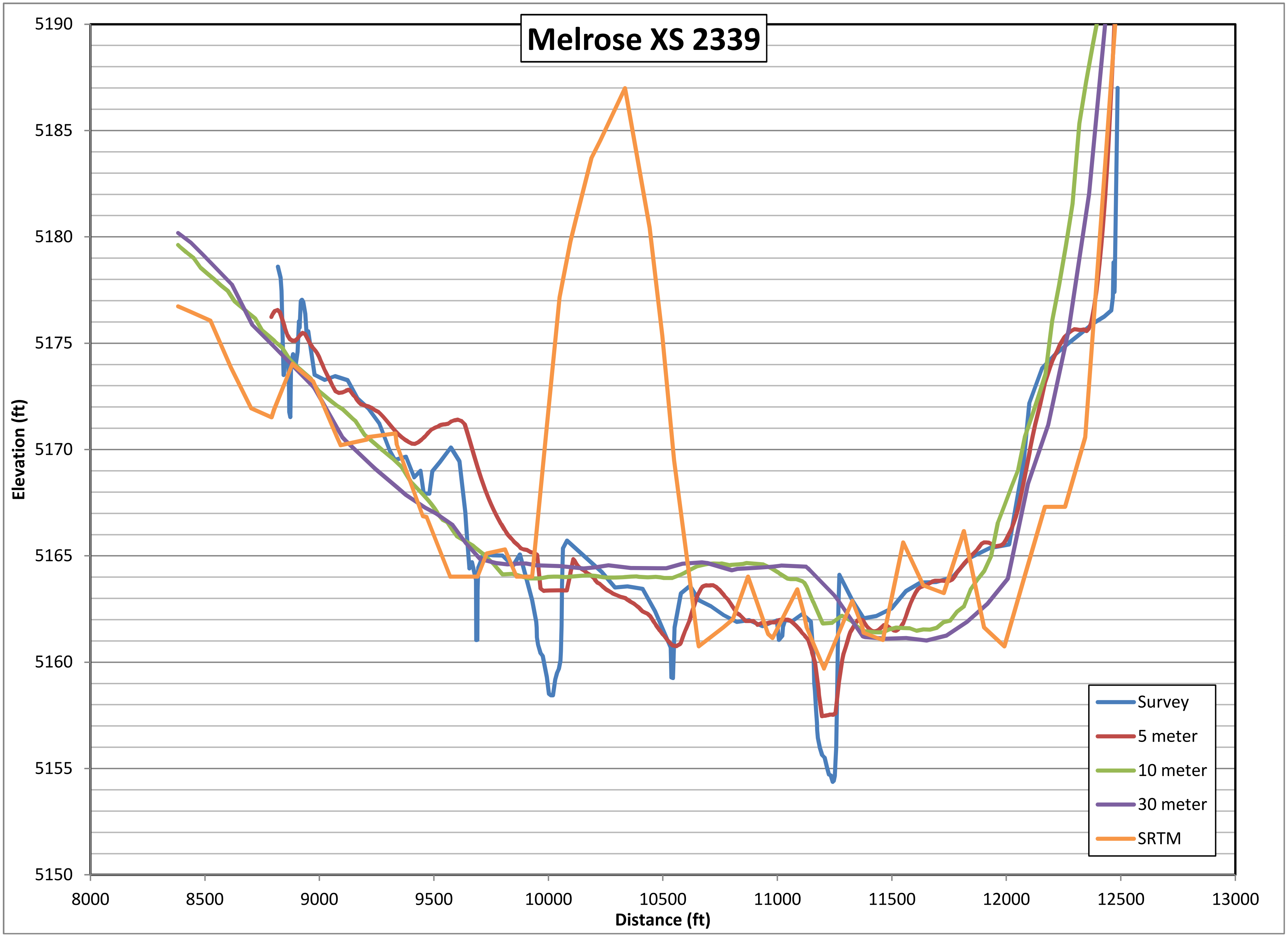
Melrose Assessment Area Profile
Survey Channel
5 m Channel
10 m Channel
30 m Channel
SRTM Channel
Cross Sections
Survey WSEL
5 m WSEL
10 m WSEL
30 m WSEL
SRTM WSEL
Trapper Creek Rd Crossing
XS 255
XS 1432
XS 2339
XS 3215
XS 3312
XS 3704
XS 4374
XS 5012
Elevation (ft NAVD88)
Channel Distance (ft)
5190
5185
5180
5175
5170
5165
5160
5155
5150
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500



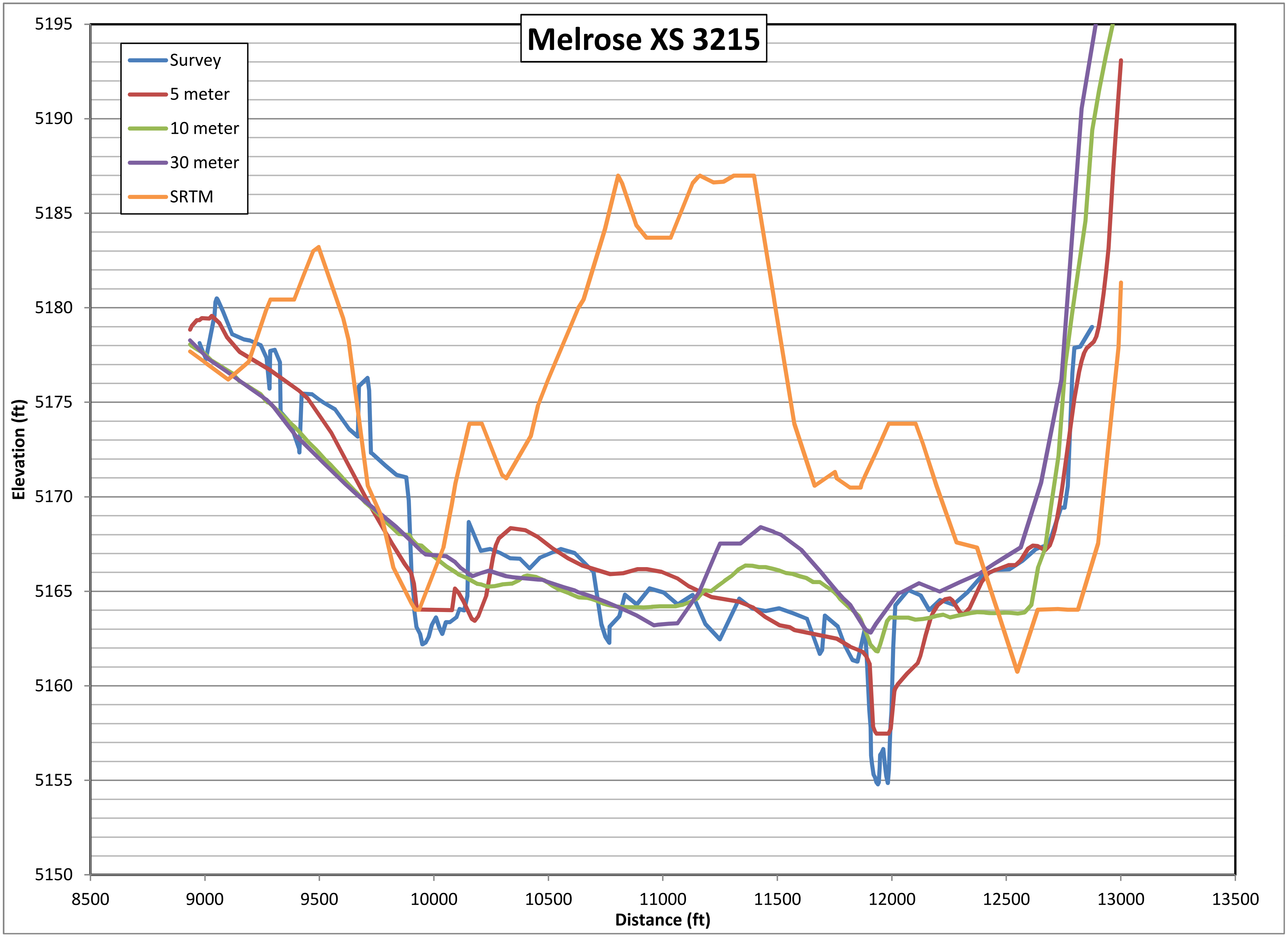
Melrose XS 254
Elevation (ft)
5190
5185
5180
5175
5170
5165
5160
5155
5150
8500
9000
9500
10000
10500
11000
11500
12000
12500
Distance (ft)
Survey
5 meter
10 meter
30 meter
SRTM

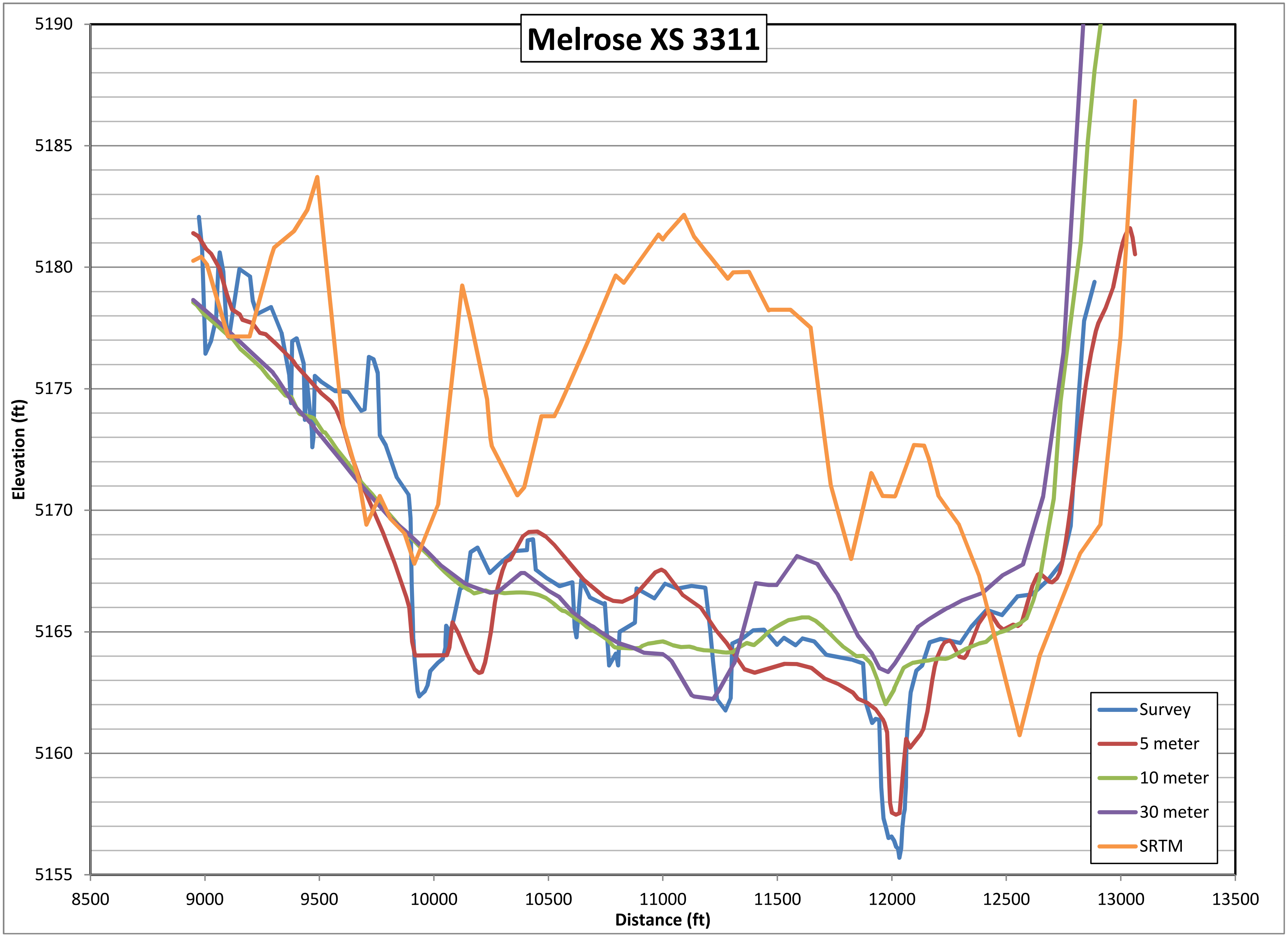


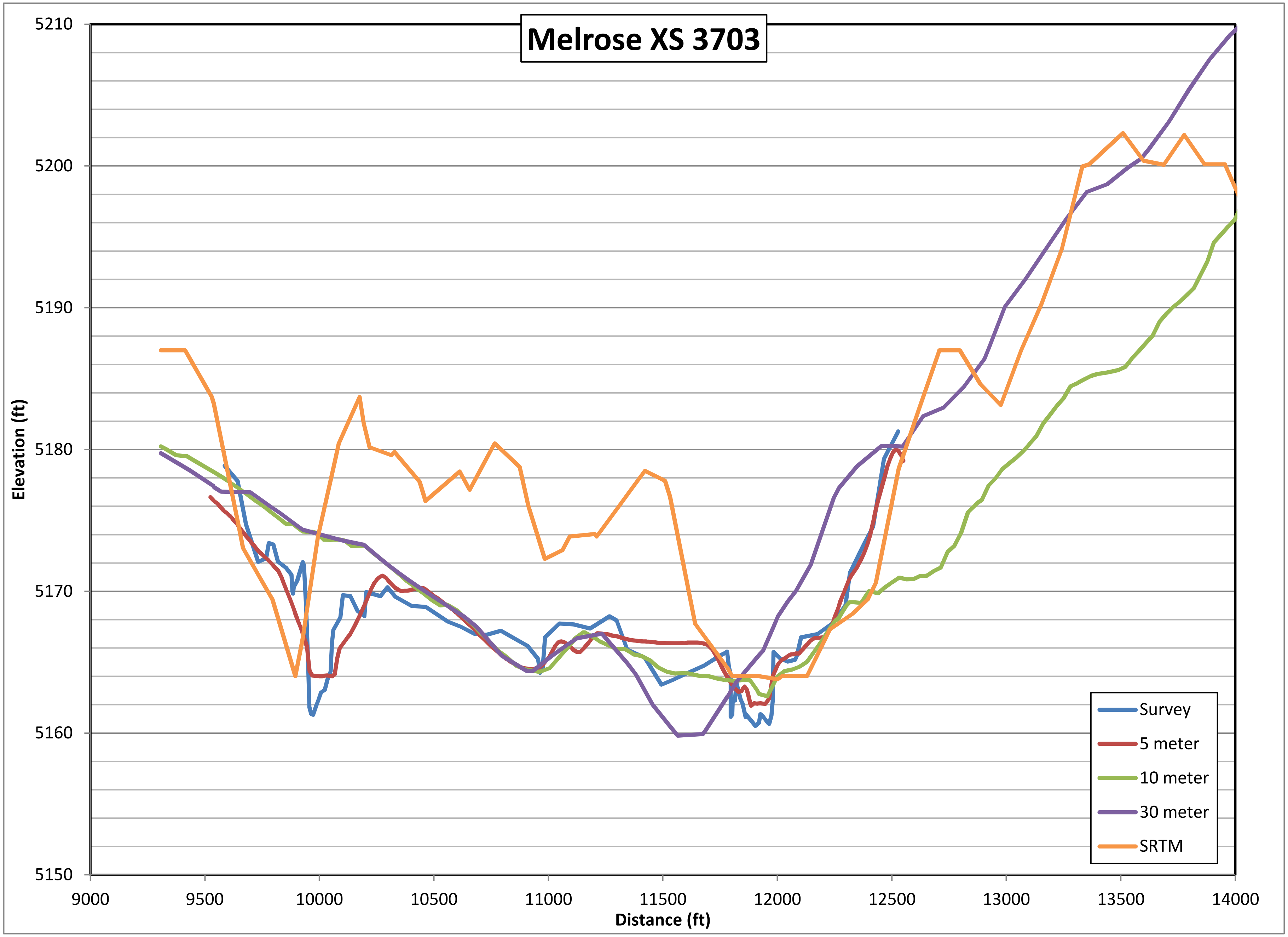
Melrose XS 1431
Elevation (ft)
Distance (ft)
5195
5190
5185
5180
5175
5170
5165
5160
5155
5150
9000
9500
10000
10500
11000
11500
12000
12500
13000
13500
Survey
5 meter
10 meter
30 meter
SRTM

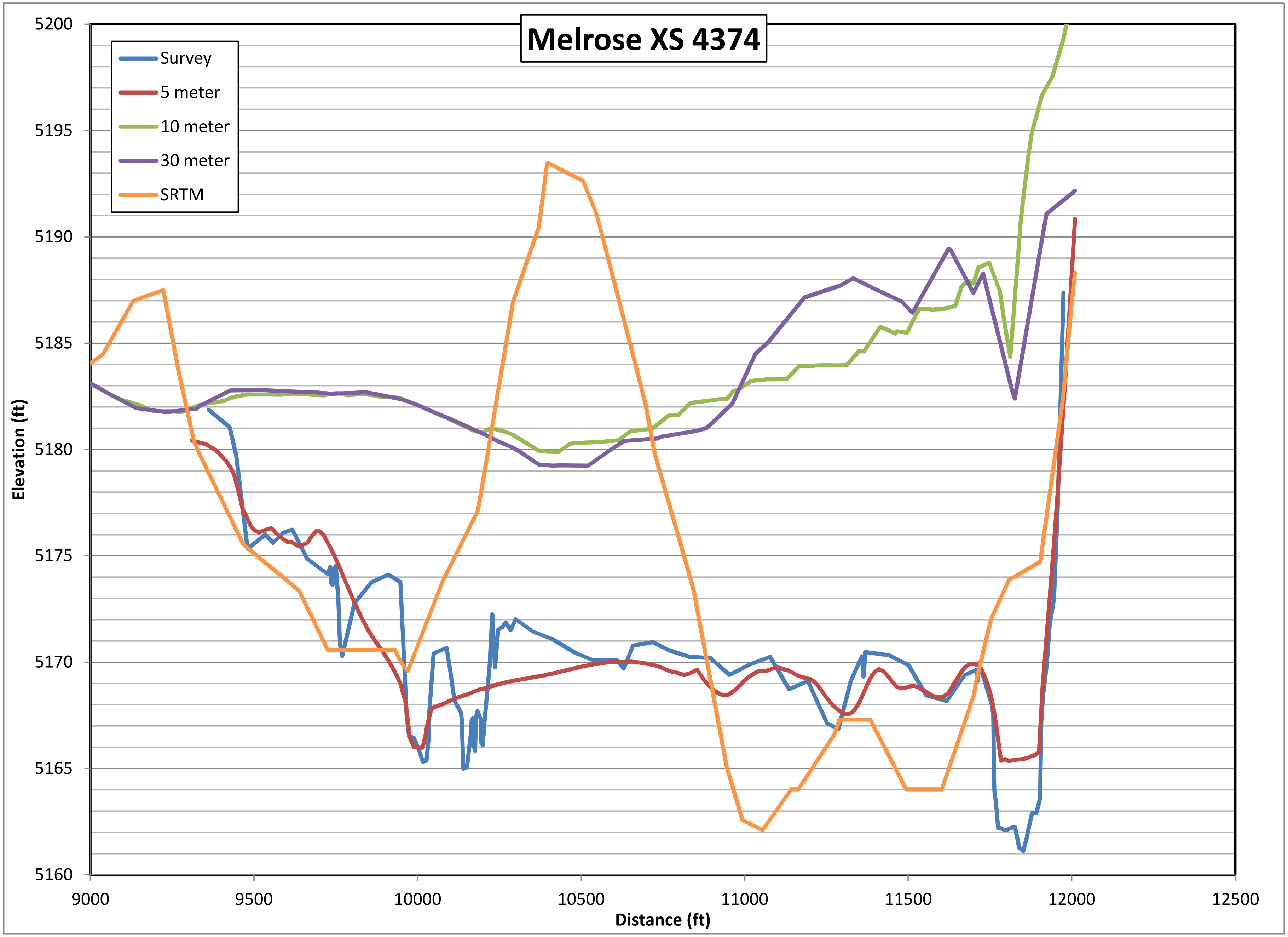


Melrose XS 2339
Elevation (ft)
Distance (ft)
5190
5185
5180
5175
5170
5165
5160
5155
5150
8000
8500
9000
9500
10000
10500
11000
11500
12000
12500
13000
Survey
5 meter
10 meter
30 meter
SRTM

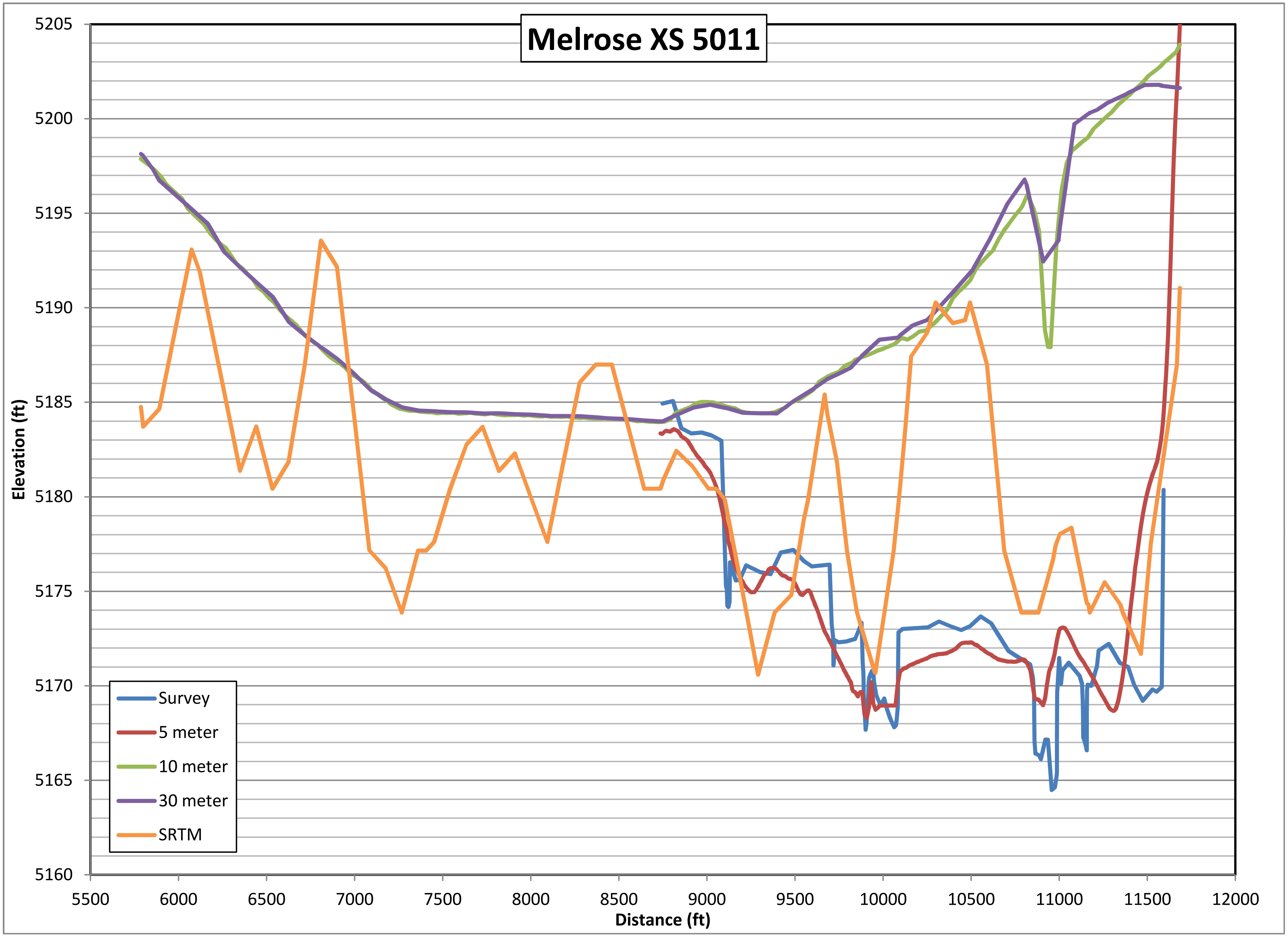

Melrose XS 3215
Survey
5 meter
10 meter
30 meter
SRTM
Elevation (ft)
Distance (ft)
5195
5190
5185
5180
5175
5170
5165
5160
5155
5150
8500
9000
9500
10000
10500
11000
11500
12000
12500
13000
13500


Melrose XS 3311
Elevation (ft)
Distance (ft)
5190
5185
5180
5175
5170
5165
5160
5155
8500
9000
9500
10000
10500
11000
11500
12000
12500
13000
13500
Survey
5 meter
10 meter
30 meter
SRTM


Melrose XS 3703
Elevation (ft)
Distance (ft)
5210
5200
5190
5180
5170
5160
5150
9000
9500
10000
10500
11000
11500
12000
12500
13000
13500
14000
Survey
5 meter
10 meter
30 meter
SRTM



Melrose XS 4374
Survey
5 meter
10 meter
30 meter
SRTM
Elevation (ft)
Distance (ft)
5200
5195
5190
5185
5180
5175
5170
5165
5160
9000
9500
10000
10500
11000
11500
12000
12500



Melrose XS 5011
Elevation (ft)
5205
5200
5195
5190
5185
5180
5175
5170
5165
5160
5500
6000
6500
7000
7500
8000
8500
9000
9500
10000
10500
11000
11500
12000
Distance (ft)
Survey
5 meter
10 meter
30 meter
SRTM

Appendix E. Field Survey Data

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Big Hole River (Beaverhead, Silverbow, & Deerlodge Counties) Survey Methodology Report:
The Big Hole River had 22 cross sections surveyed in three sites. The survey control and portion of the point data collection was done using Trimble 4800 Dual Frequency survey grade GPS units. The horizontal & vertical (XYZ) control was derived from published data from National Geodetic Survey's datasheets and verified with their Online Positional Users Service (OPUS) with the following results:

Melrose Site:
Control point "Melrose " USGS CBN (Cooperative Base Network Control Station) PID QY0202 was remotely tied July 12, 2012 with a base that had an eight hour and twenty-four minute occupation with a **"peak to peak error"** of 0.013(m) in northing, 0.010(m) in easting and 0.013(m) in elliptical height. Five RTK ties were made to the point. The XY&Z results of ties were within 0.01m.

Wisdom Site:
Control point "QY0267(D70)" July 6,2012 was surveyed using multiple Real Time Kinematic (RTK) measurements with a base that had an six hour and forty-two minute occupation with a **"peak to peak error"** of 0.006(m) in northing, 0.002(m) in easting and 0.007(m) in elliptical height. RTK tie were made to the point. The Z results of tie were within 0.02m. There are no precise XY coordinates published by NGS.

SCS Site:
Control point "QY0257(U69)" July 3,2012 was surveyed using Real Time Kinematic (RTK) technology with a base that had an five hour and eight minute occupation and a **"peak to peak error"** of 0.025(m) in northing, 0.011(m) in easting and 0.014(m) in elliptical height. RTK tie was made to the point. Cross section datum was established using a mean elevation of the OPUS solution and the tied NGS point. The mean is within 0.02 m of either value. There are no precise XY coordinates published by NGS.

The vertical control is from National Geodetic Survey monuments PIDs noted above. The elevations were based on NAD83 ellipsoid with Geoid 09 separation applied.

In areas where GPS use was not practical, control was set near the structure by GPS and Trimble 5603 series lazar total station was used.

Attached are the National Geodetic Survey data sheets for the vertical control and the OPUS "NGS-OPUS SOLUTION REPORTS" for the horizontal control.

All horizontal survey data collected for this survey is in Montana State Plane co-ordinates (2500MT) in International feet.

All vertical data collected for this survey is in NAVD 88 Geoid09 in US feet.
Dates of survey:

- June and July 2012

Roger A. Austin PLS Reg. No. 12252 LS Date: 04-16-2013

The NGS Data Sheet

See file dsdata.txt for more information about the datasheet.

```
PROGRAM = datasheet95, VERSION = 8.1
1        National Geodetic Survey,   Retrieval Date = APRIL 22, 2013
 QY0202 ***********************************************************************
 QY0202  CBN           -  This is a Cooperative Base Network Control Station.
 QY0202  DESIGNATION -  MELROSE
 QY0202  PID         -  QY0202
 QY0202  STATE/COUNTY-  MT/SILVER BOW
 QY0202  COUNTRY     -  US
 QY0202  USGS QUAD   -  MELROSE (1988)
 QY0202
 QY0202                        *CURRENT SURVEY CONTROL
 QY0202  ___________________________________________________________________
 QY0202* NAD 83(2011) POSITION- 45 38 20.10486(N) 112 41 10.49890(W)   ADJUSTED
 QY0202* NAD 83(2011) ELLIP HT-  1572.479 (meters)        (06/27/12)   ADJUSTED
 QY0202* NAD 83(2011) EPOCH   -  2010.00
 QY0202* NAVD 88 ORTHO HEIGHT -  1584.236  (meters)    5197.61  (feet) ADJUSTED
 QY0202  ___________________________________________________________________
 QY0202  NAD 83(2011) X  - -1,723,316.505 (meters)                     COMP
 QY0202  NAD 83(2011) Y  - -4,122,499.409 (meters)                     COMP
 QY0202  NAD 83(2011) Z  -  4,538,401.950 (meters)                     COMP
 QY0202  LAPLACE CORR    -         2.84   (seconds)                    DEFLEC12A
 QY0202  GEOID HEIGHT    -       -11.75   (meters)                     GEOID12A
 QY0202  DYNAMIC HEIGHT  -      1583.621  (meters)    5195.60  (feet)  COMP
 QY0202  MODELED GRAVITY -    980,171.7   (mgal)                       NAVD 88
 QY0202
 QY0202  VERT ORDER      -  FIRST     CLASS II
 QY0202
 QY0202  FGDC Geospatial Positioning Accuracy Standards (95% confidence, cm)
 QY0202  Type                                        Horiz  Ellip  Dist(km)
 QY0202  -------------------------------------------------------------------
 QY0202  NETWORK                                      2.59   3.49
 QY0202  -------------------------------------------------------------------
 QY0202  MEDIAN LOCAL ACCURACY AND DIST (010 points)  2.60   3.48    55.97
 QY0202  -------------------------------------------------------------------
 QY0202  NOTE: Click here for information on individual local accuracy
 QY0202  values and other accuracy information.
 QY0202
 QY0202
 QY0202.The horizontal coordinates were established by GPS observations
 QY0202.and adjusted by the National Geodetic Survey in June 2012.
 QY0202
 QY0202.NAD 83(2011) refers to NAD 83 coordinates where the reference
 QY0202.frame has been affixed to the stable North American tectonic plate. See
 QY0202.NA2011 for more information.
 QY0202
 QY0202.The horizontal coordinates are valid at the epoch date displayed above
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QY0202.which is a decimal equivalence of Year/Month/Day.
QY0202
QY0202.The orthometric height was determined by differential leveling and
QY0202.adjusted by the NATIONAL GEODETIC SURVEY
QY0202.in June 1991.
QY0202
QY0202.The X, Y, and Z were computed from the position and the ellipsoidal ht.
QY0202
QY0202.The Laplace correction was computed from DEFLEC12A derived deflections.
QY0202
QY0202.The ellipsoidal height was determined by GPS observations
QY0202.and is referenced to NAD 83.
QY0202
QY0202.The dynamic height is computed by dividing the NAVD 88
QY0202.geopotential number by the normal gravity value computed on the
QY0202.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
QY0202.degrees latitude (g = 980.6199 gals.).
QY0202
QY0202.The modeled gravity was interpolated from observed gravity values.
QY0202
QY0202. The following values were computed from the NAD 83(2011) position.
QY0202
QY0202;                  North         East     Units Scale Factor Converg.
QY0202;SPC MT     -   159,410.681   351,730.849   MT  0.99967662   -2 19 50.7
QY0202;SPC MT     -   523,000.92  1,153,972.60   iFT  0.99967662   -2 19 50.7
QY0202;UTM  12    - 5,055,312.870   368,583.460   MT  0.99981233   -1 12 20.7
QY0202
QY0202!           -  Elev Factor  x  Scale Factor =   Combined Factor
QY0202!SPC MT     -   0.99975354  x   0.99967662  =   0.99943024
QY0202!UTM  12    -   0.99975354  x   0.99981233  =   0.99956591
QY0202
QY0202:              Primary Azimuth Mark                     Grid Az
QY0202:SPC MT     -  MELROSE AZ MK                            340 21 49.5
QY0202:UTM  12    -  MELROSE AZ MK                            339 14 19.5
QY0202
QY0202|---------------------------------------------------------------------|
QY0202| PID    Reference Object                    Distance      Geod. Az  |
QY0202|                                                          dddmmss.s |
QY0202| QY0203 MELROSE RM 1                         6.470 METERS 06814     |
QY0202| QY0201 MELROSE RM 2                         9.828 METERS 15836     |
QY0202| QY0204 MELROSE AZ MK                                     3380158.8 |
QY0202|---------------------------------------------------------------------|
QY0202
QY0202                   SUPERSEDED SURVEY CONTROL
QY0202
QY0202  NAD 83(2007)-  45 38 20.10460(N)    112 41 10.50004(W) AD(       ) 0
QY0202  ELLIP H (02/10/07) 1572.509  (m)                       GP(       )
QY0202  NAD 83(1999)-  45 38 20.10459(N)    112 41 10.50039(W) AD(       ) B
QY0202  ELLIP H (04/26/01) 1572.503  (m)                       GP(       ) 4 1
QY0202  NAD 83(1992)-  45 38 20.10302(N)    112 41 10.49889(W) AD(       ) B
QY0202  ELLIP H (03/21/94) 1572.611  (m)                       GP(       ) 2 2
QY0202  NAD 83(1990)-  45 38 20.10802(N)    112 41 10.49060(W) AD(       ) 2
QY0202  NAD 83(1986)-  45 38 20.10832(N)    112 41 10.48854(W) AD(       ) 2
QY0202  NAD 27      -  45 38 20.37100(N)    112 41 07.40300(W) AD(       ) 2
QY0202  NAVD 88 (03/21/94) 1584.24   (m)         5197.6    (f) LEVELING    3
QY0202  NGVD 29 (??/??/92) 1583.039  (m)         5193.69   (f) ADJ UNCH    1 2
QY0202
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QY0202.Superseded values are not recommended for survey control.
QY0202
QY0202.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
QY0202.See file dsdata.txt to determine how the superseded data were derived.
QY0202
QY0202_U.S. NATIONAL GRID SPATIAL ADDRESS: 12TUR6858355312(NAD 83)
QY0202
QY0202_MARKER: DS = TRIANGULATION STATION DISK
QY0202_SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT
QY0202_SP_SET: CONCRETE POST
QY0202_STAMPING: MELROSE 1956
QY0202_MARK LOGO: CGS
QY0202_MAGNETIC: N = NO MAGNETIC MATERIAL
QY0202_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
QY0202+STABILITY: SURFACE MOTION
QY0202_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
QY0202+SATELLITE: SATELLITE OBSERVATIONS - July 23, 2009
QY0202
QY0202  HISTORY     - Date     Condition        Report By
QY0202  HISTORY     - 1956     MONUMENTED       CGS
QY0202  HISTORY     - 1962     GOOD             CGS
QY0202  HISTORY     - 1967     SEE DESCRIPTION  LOCENG
QY0202  HISTORY     - 19931116 GOOD             NGS
QY0202  HISTORY     - 19940219 GOOD             MTDOT
QY0202  HISTORY     - 19940616 GOOD             MTDOT
QY0202  HISTORY     - 20090723 GOOD             GEOCAC
QY0202
QY0202                          STATION DESCRIPTION
QY0202
QY0202'DESCRIBED BY COAST AND GEODETIC SURVEY 1956 (WFD)
QY0202'THE STATION IS LOCATED 0.4 MILE NORTH OF THE VILLAGE OF
QY0202'MELROSE, 108 FEET EAST OF THE CENTERLINE OF U.S. HIGHWAY 91,
QY0202'100 FEET WEST OF A WIRE FENCE AND 7 FEET NORTHEAST OF A WHITE
QY0202'4 IN X 4 IN WITNESS POST.
QY0202'
QY0202'TO REACH FROM THE RAILROAD DEPOT IN THE VILLAGE OF MELROSE.
QY0202'GO NORTH ON U.S. HIGHWAY 91 FOR 0.4 MILE TO THE STATION ON THE
QY0202'RIGHT HAND SIDE OF THE ROAD.  FROM THIS POINT CONTINUE NORTH ON
QY0202'U.S. HIGHWAY 91 FOR 0.3 MILE.  TURN LEFT, CROSS OVER THE RAILROAD
QY0202'TRACKS, AND GO ABOUT 100 YARDS TO THE AZIMUTH MARK ON THE RIGHT
QY0202'HAND SIDE OF THE DIRT LANE.
QY0202'
QY0202'THE STATION MARK PROJECTS 3 INCHES, AND THE DISK IS STAMPED
QY0202'MELROSE 1956.
QY0202'
QY0202'REFERENCE MARK 1 IS LOCATED AT THE SAME ELEVATION AS THE STATION.
QY0202'IT PROJECTS 4 INCHES, AND THE DISK IS STAMPED MELROSE NO 1
QY0202'1956.
QY0202'
QY0202'REFERENCE MARK 2 IS LOCATED AT THE SAME ELEVATION AS THE
QY0202'STATION.  IT PROJECTS 6 INCHES, AND THE DISK IS STAMPED MELROSE
QY0202'NO 2 1956.
QY0202'
QY0202'THE AZIMUTH MARK IS 55 FEET WEST OF THE WEST RAIL OF THE RAILROAD
QY0202'TRACKS, 20 FEET NORTH OF THE CENTER OF A GRADED LANE, 4 FEET
QY0202'SOUTHEAST OF A WHITE 4 IN X 4 IN WITNESS POST AND 2 FEET SOUTH
QY0202'OF A WIRE FENCE.  IT PROJECTS 4 INCHES, AND THE DISK IS STAMPED
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QY0202'MELROSE 1956.
QY0202
QY0202                              STATION RECOVERY (1962)
QY0202
QY0202'RECOVERY NOTE BY COAST AND GEODETIC SURVEY 1962
QY0202'0.5 MI N FROM MELROSE.
QY0202'0.5 MILE NORTH ALONG THE UNION PACIFIC RAILROAD FROM THE STATION SIGN
QY0202'AT MELROSE, 151 1/2 FEET NORTHEAST OF THE SECOND POLE NORTH OF
QY0202'MILEPOLE 359 1/4, 106 FEET EAST OF THE CENTER LINE OF U.S. HIGHWAY 91,
QY0202'168.9 FEET EAST AND ACROSS THE HIGHWAY FROM THE EAST RAIL, 6.7 FEET
QY0202'NORTHEAST OF A WITNESS POST, ABOUT LEVEL WITH THE HIGHWAY, AND SET IN
QY0202'THE TOP OF A CONCRETE POST PROJECTING 0.1 FOOT ABOVE THE GROUND.
QY0202
QY0202                              STATION RECOVERY (1967)
QY0202
QY0202'RECOVERY NOTE BY LOCAL ENGINEER (INDIVIDUAL OR FIRM) 1967 (KRG)
QY0202'RECOVERED BY HARRY P. JONES AND ASSOC.
QY0202'
QY0202'MELROSE-GOOD
QY0202'
QY0202'AZ MK AND R.M. 1 AND R.M. 2-GOOD
QY0202'
QY0202'NO CHANGE
QY0202
QY0202                              STATION RECOVERY (1993)
QY0202
QY0202'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1993
QY0202'THE STATION WAS RECOVERED IN GOOD CONDITION.  THE AZIMUTH AND
QY0202
QY0202                              STATION RECOVERY (1994)
QY0202
QY0202'RECOVERY NOTE BY MONTANA DEPARTMENT OF TRANSPORTATION 1994
QY0202'THE STATION WAS RECOVERED IN GOOD CONDITION. THE AZIMUTH AND REFERENCE
QY0202
QY0202                              STATION RECOVERY (1994)
QY0202
QY0202'RECOVERY NOTE BY MONTANA DEPARTMENT OF TRANSPORTATION 1994 (DRD)
QY0202'RECOVERED AS DESCRIBED.
QY0202
QY0202                              STATION RECOVERY (2009)
QY0202
QY0202'RECOVERY NOTE BY GEOCACHING 2009 (MEL)
QY0202'HH2   453820.1 1124110.6
QY0202'
1        National Geodetic Survey,   Retrieval Date = APRIL 22, 2013
QY0267 ***********************************************************************
QY0267  DESIGNATION -  D 70
QY0267  PID         -  QY0267
QY0267  STATE/COUNTY-  MT/BEAVERHEAD
QY0267  COUNTRY     -  US
QY0267  USGS QUAD   -  MUD LAKE (1994)
QY0267
QY0267                          *CURRENT SURVEY CONTROL
QY0267  ___________________________________________________________________
QY0267* NAD 83(1992) POSITION- 45 43 25.22967(N) 113 23 29.86726(W)   ADJUSTED
QY0267* NAVD 88 ORTHO HEIGHT -  1820.457  (meters)    5972.62  (feet) ADJUSTED
QY0267  ___________________________________________________________________
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QY0267  LAPLACE CORR    -         10.27  (seconds)                        DEFLEC12A
QY0267  GEOID HEIGHT    -        -12.93  (meters)                         GEOID12A
QY0267  DYNAMIC HEIGHT  -      1819.620  (meters)     5969.87  (feet) COMP
QY0267  MODELED GRAVITY -    980,092.0   (mgal)                           NAVD 88
QY0267
QY0267  HORZ ORDER      -  THIRD
QY0267  VERT ORDER      -  SECOND    CLASS 0
QY0267
QY0267.The horizontal coordinates were established by classical geodetic methods
QY0267.and adjusted by the National Geodetic Survey in July 1992.
QY0267.
QY0267.The orthometric height was determined by differential leveling and
QY0267.adjusted by the NATIONAL GEODETIC SURVEY
QY0267.in June 1991.
QY0267
QY0267.The Laplace correction was computed from DEFLEC12A derived deflections.
QY0267
QY0267.The dynamic height is computed by dividing the NAVD 88
QY0267.geopotential number by the normal gravity value computed on the
QY0267.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
QY0267.degrees latitude (g = 980.6199 gals.).
QY0267
QY0267.The modeled gravity was interpolated from observed gravity values.
QY0267
QY0267. The following values were computed from the NAD 83(1992) position.
QY0267
QY0267;                     North         East     Units Scale Factor Converg.
QY0267;SPC MT       -   171,299.321   297,277.217   MT  0.99964278   -2 50 48.3
QY0267;SPC MT       -   562,005.65    975,318.95    iFT 0.99964278   -2 50 48.3
QY0267;UTM  12      - 5,066,128.469   313,892.174   MT  1.00002584   -1 42 46.3
QY0267
QY0267!             -  Elev Factor  x  Scale Factor =   Combined Factor
QY0267!SPC MT       -   0.99971671  x   0.99964278  =   0.99935959
QY0267!UTM  12      -   0.99971671  x   1.00002584  =   0.99974254
QY0267
QY0267                          SUPERSEDED SURVEY CONTROL
QY0267
QY0267  NAD 83(1990)-  45 43 25.22733(N)    113 23 29.86984(W) AD(       ) 3
QY0267  NGVD 29 (??/??/92) 1819.170  (m)          5968.39   (f) ADJ UNCH    2 0
QY0267
QY0267.Superseded values are not recommended for survey control.
QY0267
QY0267.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
QY0267.See file dsdata.txt to determine how the superseded data were derived.
QY0267
QY0267_U.S. NATIONAL GRID SPATIAL ADDRESS: 12TUR1389266128(NAD 83)
QY0267
QY0267_MARKER: DB = BENCH MARK DISK
QY0267_SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT
QY0267_SP_SET: SET IN TOP OF CONCRETE MONUMENT
QY0267_STAMPING: D 70 1934
QY0267_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
QY0267+STABILITY: SURFACE MOTION
QY0267
QY0267  HISTORY     - Date     Condition        Report By
QY0267  HISTORY     - 1934     MONUMENTED       CGS
QY0267  HISTORY     - 1960     GOOD             USGS
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QY0267  HISTORY     - 1960      GOOD             USGS
QY0267
QY0267                           STATION DESCRIPTION
QY0267
QY0267'DESCRIBED BY US GEOLOGICAL SURVEY 1960
QY0267'ESTABLISHED AS A SECOND-ORDER BENCH MARK IN 1934 BY THE NGS, LINE 1,
QY0267'MONTANA.
QY0267'
QY0267'STATION IS LOCATED ON A SECTION OF OLD STATE HIGHWAY NO.43 AT
QY0267'A POINT 8.2 MI. FROM THE POST OFFICE AT WISDOM, MONTANA, AND 870
QY0267'FT. S. OF THE PRESENT HIGHWAY.
QY0267'
QY0267'TO REACH FROM WISDOM POST OFFICE, GO E. ON HIGHWAY 274 FOR 0.2
QY0267'MI. TO BEND TO N. TURN N. AND FOLLOW STATE HIGHWAY 43 FOR 7.5 MI.
QY0267'TO A SERVICE RD. RIGHT.  TURN RIGHT (S.) TO OLD TRACE OF ABANDONED
QY0267'HIGHWAY AND GATE.  GO THRU GATE AND FOLLOW OLD HIGHWAY FOR 0.7 MI.
QY0267'IN AN EASTERLY DIRECTION.  STATION IS ON THE TOP OF A BANK ON
QY0267'THE NW. SIDE OF A HIGHWAY AND IS 45 FT. FROM THE CENTERLINE OF RD.
QY0267'STATION IS 6 FT. SE. OF TRACE OF OLD FENCE LINE.
QY0267'
QY0267'STATION MARK - - A STANDARD USC AND GS DISK STAMPED--- D-70-1934
QY0267'--- AND SET IN THE TOP OF CONCRETE POST PROJECTING 0.2 FT.
QY0267'ABOVE GROUND.
QY0267
QY0267                           STATION RECOVERY (1960)
QY0267
QY0267'RECOVERY NOTE BY US GEOLOGICAL SURVEY 1960
QY0267'7.8 MI N FROM WISDOM.
QY0267'7.8 MILES NORTH ALONG STATE HIGHWAY 274 FROM THE PUBLIC SCHOOL IN
QY0267'WISDOM, BEAVERHEAD COUNTY, 0.2 MILES SOUTH ON SERVICE ROAD TO OLD
QY0267'STATE HIGHWAY, 0.7 MILES NORTH ALONG OLD HIGHWAY, THE BENCH MARK IS ON
QY0267'TOP OF A BANK 45 FEET NORTHWEST OF THE CENTERLINE OF THE HIGHWAY. A
QY0267'STANDARD DISK, STAMPED D 70 1934 AND SET IN THE TOP OF A CONCRETE
QY0267'POST.
 1        National Geodetic Survey,   Retrieval Date = APRIL 22, 2013
QY0257 ***********************************************************************
QY0257  DESIGNATION -  U 69
QY0257  PID         -  QY0257
QY0257  STATE/COUNTY-  MT/DEER LODGE
QY0257  COUNTRY     -  US
QY0257  USGS QUAD   -  LOWER SEYMOUR LAKE (1994)
QY0257
QY0257                          *CURRENT SURVEY CONTROL
QY0257  ______________________________________________________________________
QY0257* NAD 83(1986) POSITION- 45 52 48.     (N) 113 11 35.     (W)   SCALED
QY0257* NAVD 88 ORTHO HEIGHT -   1778.197  (meters)    5833.97  (feet) ADJUSTED
QY0257  ______________________________________________________________________
QY0257  GEOID HEIGHT    -          -12.51  (meters)                    GEOID12A
QY0257  DYNAMIC HEIGHT  -        1777.417  (meters)    5831.41  (feet) COMP
QY0257  MODELED GRAVITY -     980,114.2    (mgal)                      NAVD 88
QY0257
QY0257  VERT ORDER      -  SECOND    CLASS 0
QY0257
QY0257.The horizontal coordinates were scaled from a topographic map and have
QY0257.an estimated accuracy of +/- 6 seconds.
QY0257.
QY0257.The orthometric height was determined by differential leveling and
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QY0257.adjusted by the NATIONAL GEODETIC SURVEY
QY0257.in June 1991.
QY0257
QY0257.The dynamic height is computed by dividing the NAVD 88
QY0257.geopotential number by the normal gravity value computed on the
QY0257.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
QY0257.degrees latitude (g = 980.6199 gals.).
QY0257
QY0257.The modeled gravity was interpolated from observed gravity values.
QY0257
QY0257;                   North          East     Units  Estimated Accuracy
QY0257;SPC MT       -   187,900.      313,530.      MT  (+/- 180 meters Scaled)
QY0257
QY0257                              SUPERSEDED SURVEY CONTROL
QY0257
QY0257  NGVD 29 (??/??/92) 1776.929  (m)          5829.81   (f) ADJ UNCH    2 0
QY0257
QY0257.Superseded values are not recommended for survey control.
QY0257
QY0257.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
QY0257.See file dsdata.txt to determine how the superseded data were derived.
QY0257
QY0257_U.S. NATIONAL GRID SPATIAL ADDRESS: 12TUR298830(NAD 83)
QY0257
QY0257_MARKER: DB = BENCH MARK DISK
QY0257_SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT
QY0257_SP_SET: SET IN TOP OF CONCRETE MONUMENT
QY0257_STAMPING: U 69 1934
QY0257_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
QY0257+STABILITY: SURFACE MOTION
QY0257
QY0257  HISTORY     - Date     Condition        Report By
QY0257  HISTORY     - 1934     MONUMENTED       CGS
QY0257  HISTORY     - 1960     GOOD             USGS
QY0257
QY0257                          STATION DESCRIPTION
QY0257
QY0257'DESCRIBED BY US GEOLOGICAL SURVEY 1960
QY0257'2.0 MI E FROM FISHTRAP.
QY0257'2.0 MILES EAST ALONG THE NEW HIGHWAY 274 FROM THE POST OFFICE AT
QY0257'FISHTRAP, DEER LODGE COUNTY, 240 FEET NORTH OF THE CENTERLINE OF THE
QY0257'NEW HIGHWAY AND T-ROAD NORTH, 12 FEET EAST OF THE WEST CORNER OF AN
QY0257'ABANDONED ONE-ROOM LOG CABIN, 200 FEET SOUTHWEST OF A FENCE LINE AND
QY0257'OLD HIGHWAY AND 33 FEET NORTHWEST OF THE CENTERLINE OF THE OLD
QY0257'HIGHWAY.  A STANDARD DISK STAMPED U 69 1934 AND SET IN THE TOP OF A
QY0257'CONCRETE POST.

*** retrieval complete.
Elapsed Time = 00:00:08
```

```
                    OPUS solution  26991851.DAT OP1341503820401.txt
From:    opus [opus@ngs.noaa.gov]
Sent:    Thursday, July 05, 2012 9:58 AM
To:      Roger Austin
Subject:         OPUS solution : 26991851.DAT OP1341503820401

 FILE: 26991851.DAT OP1341503820401

                              NGS OPUS SOLUTION REPORT
                              ========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

      USER: rogera@pcimontana.com                      DATE: July 05, 2012
RINEX FILE: 2699185p.12o                               TIME: 15:58:03 UTC


  SOFTWARE: page5  1108.09 master73.pl 062112      START: 2012/07/03  15:26:00
 EPHEMERIS: igr16952.eph [rapid]                    STOP: 2012/07/03  20:34:00
  NAV FILE: brdc1850.12n                        OBS USED: 12975 / 13382   :
97%
  ANT NAME: TRM22020.00+GP  NONE             # FIXED AMB:     72 /    86   :
84%
ARP HEIGHT: 1.4381                           OVERALL RMS: 0.017(m)


 REF FRAME: NAD_83(2011)(EPOCH:2010.0000)              IGS08 (EPOCH:2012.5048)

         X:      -1744791.086(m)   0.004(m)          -1744791.919(m)   0.004(m)
         Y:      -4093439.812(m)   0.022(m)          -4093438.585(m)   0.022(m)
         Z:       4556584.996(m)   0.022(m)           4556584.988(m)   0.022(m)

       LAT:   45 52 18.22070      0.025(m)        45 52 18.23916      0.025(m)
     E LON:  246 54 51.54666      0.011(m)       246 54 51.48884      0.011(m)
     W LON:  113  5  8.45334      0.011(m)       113  5  8.51116      0.011(m)
    EL HGT:          1745.626(m)  0.014(m)               1745.062(m)  0.014(m)

                         UTM COORDINATES     STATE PLANE COORDINATES
                         UTM (Zone 12)          SPC (2500 MT   )
Northing (Y) [meters]     5081910.954           186595.447
Easting (X)  [meters]      338129.111           321811.813
Convergence  [degrees]    -1.49739009           -2.62294108
Point Scale                0.99992213            0.99958879
Combined Factor            0.99964856            0.99931531

US NATIONAL GRID DESIGNATOR: 12TUR3812981910(NAD 83)


                               BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
DK6947 IDSN SALMON CORS ARP                 N451131.444 W1135348.906   98621.0
DL7705 NOMT NOMT_EBRY_MT1999 CORS ARP       N453548.889 W1113747.304  117387.0
DN6069 LOLO LOLO CORS ARP                   N464546.247 W1140548.672  126029.6

                     NEAREST NGS PUBLISHED CONTROL POINT
QY0254      S 69                            N455313.    W1130706.       3045.1

This position and the above vector components were computed without any
knowledge by the National Geodetic Survey regarding the equipment or field
operating procedures used.
```

OPUS solution 26991740.DAT OP1341503492555.txt

From: opus [opus@ngs.noaa.gov]
Sent: Thursday, July 05, 2012 9:54 AM
To: Roger Austin
Subject: OPUS solution : 26991740.DAT OP1341503492555

```
 FILE: 26991740.DAT OP1341503492555

                              NGS OPUS SOLUTION REPORT
                              ========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

      USER: rogera@pcimontana.com                       DATE: July 05, 2012
RINEX FILE: 2699174o.12o                                TIME: 15:53:43 UTC

  SOFTWARE: page5  1108.09 master13.pl 062112      START: 2012/06/22  14:13:00
 EPHEMERIS: igs16935.eph [precise]                  STOP: 2012/06/22  20:55:00
  NAV FILE: brdc1740.12n                        OBS USED: 18003 / 18564   :
97%
  ANT NAME: TRM22020.00+GP  NONE               # FIXED AMB:    77 /    82   :
94%
ARP HEIGHT: 1.5213                             OVERALL RMS: 0.011(m)

 REF FRAME: NAD_83(2011)(EPOCH:2010.0000)              IGS08 (EPOCH:2012.4747)

         X:     -1778267.121(m)   0.004(m)          -1778267.953(m)   0.004(m)
         Y:     -4100461.890(m)   0.006(m)          -4100460.662(m)   0.006(m)
         Z:      4537537.875(m)   0.004(m)           4537537.866(m)   0.004(m)

       LAT:   45 37 31.52995      0.006(m)        45 37 31.54816      0.006(m)
     E LON:  246 33 17.40998      0.002(m)       246 33 17.35220      0.002(m)
     W LON:  113 26 42.59002      0.002(m)       113 26 42.64780      0.002(m)
    EL HGT:         1831.084(m)   0.007(m)              1830.521(m)   0.007(m)

                         UTM COORDINATES    STATE PLANE COORDINATES
                          UTM (Zone 12)         SPC (2500 MT  )
Northing (Y) [meters]     5055339.044           160605.197
Easting (X)  [meters]      309392.960           292566.790
Convergence  [degrees]    -1.74828596           -2.88590397
Point Scale                1.00004669            0.99968220
Combined Factor            0.99975969            0.99939531

US NATIONAL GRID DESIGNATOR: 12TUR0939255339(NAD 83)


                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
DL7755 P706 MATADORRCHMT2006 CORS ARP      N450236.472 W1123126.669    96959.9
DL7725 P045 BIRCHCREEKMT2006 CORS ARP      N452258.325 W1123701.828    70118.6
DK6947 IDSN SALMON CORS ARP                N451131.444 W1135348.906    59770.0

                     NEAREST NGS PUBLISHED CONTROL POINT
QY0272      H 70                           N453801.    W1132640.         913.0

This position and the above vector components were computed without any
knowledge by the National Geodetic Survey regarding the equipment or field
operating procedures used.
```

OPUS solution PNT24- 26991921.DAT OP1342105243386.txt

From: opus [opus@ngs.noaa.gov]
Sent: Thursday, July 12, 2012 9:04 AM
To: Roger Austin
Subject: OPUS solution : 26991921.DAT OP1342105243386

FILE: 26991921.DAT OP1342105243386

```
                              NGS OPUS SOLUTION REPORT
                              ========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

      USER: rogera@pcimontana.com                    DATE: July 12, 2012
RINEX FILE: 2699192n.12o                             TIME: 15:03:46 UTC


  SOFTWARE: page5  1108.09 master43.pl 062112      START: 2012/07/10  13:00:00
 EPHEMERIS: igr16962.eph [rapid]                    STOP: 2012/07/10  21:24:00
  NAV FILE: brdc1920.12n                        OBS USED: 21883 / 22759    :
96%
  ANT NAME: TRM22020.00+GP  NONE               # FIXED AMB:    102 /   113    :
90%
ARP HEIGHT: 1.466                           OVERALL RMS: 0.017(m)


 REF FRAME: NAD_83(2011)(EPOCH:2010.0000)              IGS08 (EPOCH:2012.5238)

         X:     -1722551.561(m)   0.006(m)          -1722552.393(m)   0.006(m)
         Y:     -4123231.839(m)   0.011(m)          -4123230.608(m)   0.011(m)
         Z:      4538097.308(m)   0.018(m)           4538097.296(m)   0.018(m)

       LAT:   45 38  4.39036      0.013(m)        45 38  4.40896      0.013(m)
     E LON:  247 19 35.11754      0.010(m)       247 19 35.06020      0.010(m)
     W LON:  112 40 24.88246      0.010(m)       112 40 24.93980      0.010(m)
    EL HGT:         1620.972(m)   0.013(m)              1620.394(m)   0.013(m)
 ORTHO HGT:         1632.707(m)   0.023(m) [NAVD88 (Computed using GEOID12)]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 12)         SPC (2500 MT  )
Northing (Y) [meters]     5054807.201           158885.992
Easting (X)  [meters]      369560.846           352697.990
Convergence  [degrees]    -1.19660004          -2.32148599
Point Scale                0.99980918           0.99967842
Combined Factor            0.99955517           0.99942444

US NATIONAL GRID DESIGNATOR: 12TUR6956054807(NAD 83)


                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
DL7705 NOMT NOMT_EBRY_MT1999 CORS ARP      N453548.889 W1113747.304   81538.6
DL7755 P706 MATADORRCHMT2006 CORS ARP      N450236.472 W1123126.669   66747.5
DK6947 IDSN SALMON CORS ARP                N451131.444 W1135348.906  107671.6

                     NEAREST NGS PUBLISHED CONTROL POINT
QY0198      W 321                          N453742.    W1124101.       1043.7

This position and the above vector components were computed without any
knowledge by the National Geodetic Survey regarding the equipment or field
operating procedures used.
```

Appendix F. Intermap Correspondence

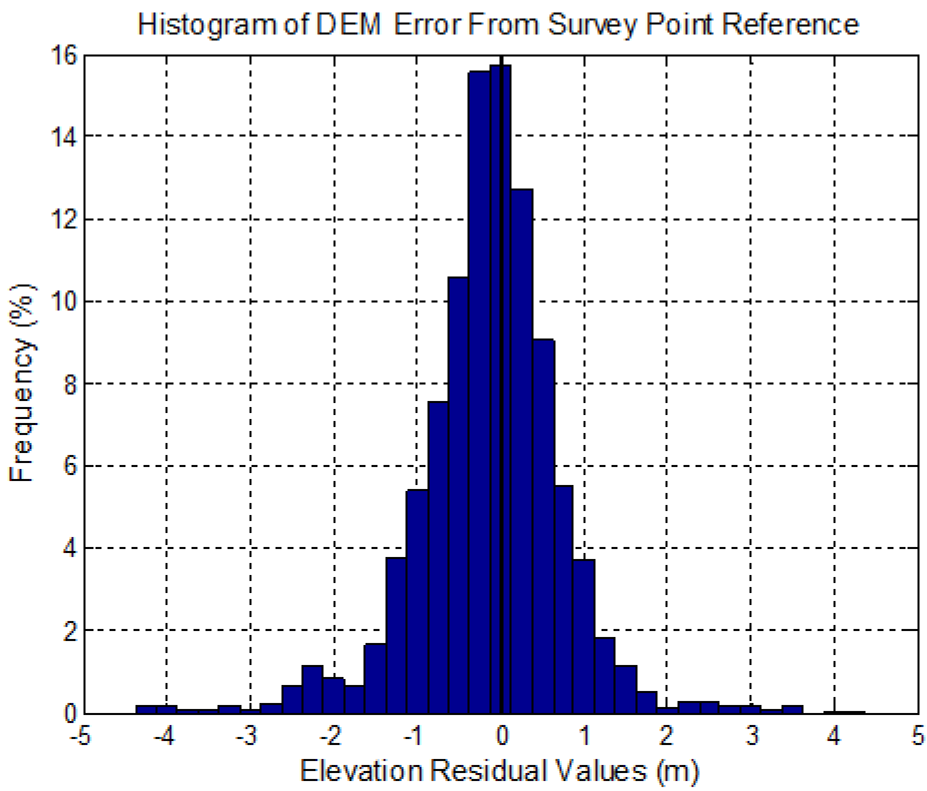
Fennelly, Benjamin T

From: Stephen Griffiths [sgriffiths@intermap.com]
Sent: Friday, July 27, 2012 3:50 PM
To: Fennelly, Benjamin T
Subject: RE: Big Hole River, MT

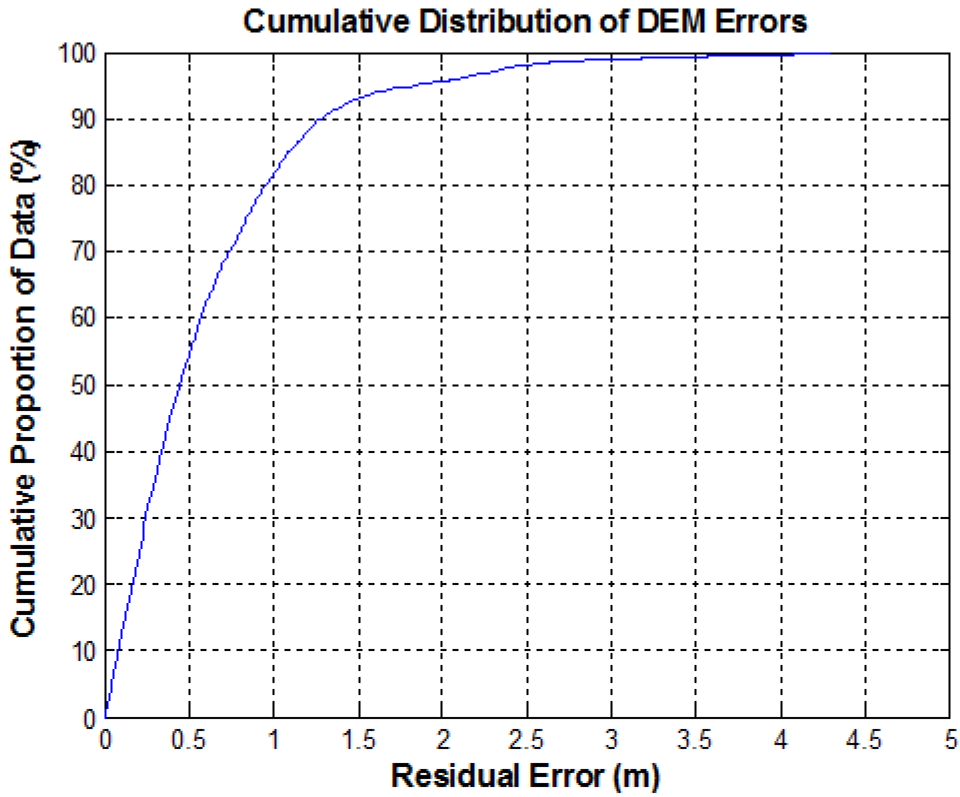
Hi Ben,

I think we have some issues with our data in some regions, and in other regions we do pretty good. Our stats show that when we look at all data in aggregate we do ok. But there are a couple of things that I don't like – there is one road where we *should* do well but don't. Turns out our DSM does better than the DTM along that road. This kind of thing points to editing. But I'd like to chat with David first and see what he thinks.

The overall stats are shown below (these are the differences between your survey points and the Intermap DTM product):



Min = -4.30 m
Max = 4.30 m
Mean = -0.14 m
Std. Dev. = 0.86 m
RMSE = 0.87 m
LE90 = 1.29 m



More to come Monday, Tuesday.

Regards,

Stephen Griffiths
R&D Manager | Intermap Technologies Corp. | Calgary, Alberta, Canada
Tel. 1.403.266.0980 Ext 305 | Fax. 1.403.265.0499 | Cell 1.403.612.7300
sgriffiths@intermap.com | www.intermap.com

From: Fennelly, Benjamin T [mailto:ben.fennelly@atkinsglobal.com]
Sent: Friday, July 27, 2012 3:43 PM
To: Stephen Griffiths
Subject: RE: Big Hole River, MT

Thanks Stephen! What's your conclusion? Do you have any insight?

Thanks again for taking the time to look at the issue.

Ben

Benjamin T. Fennelly, PE, CFM
Senior Engineer, Integrated Water Resources

ATKINS

3810 Valley Commons Drive, Suite 4, Bozeman, MT 59718 | Phone: +1 (406) 587 7275 Ext. 4111234| Fax: +1 (406) 587 7278
Email: ben.fennelly@atkinsglobal.com | Web: www.atkinsglobal.com/northamerica www.atkinsglobal.com

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From: Stephen Griffiths [mailto:sgriffiths@intermap.com]
Sent: Friday, July 27, 2012 3:40 PM

To: Fennelly, Benjamin T
Subject: RE: Big Hole River, MT

Hi Ben,

I have past our finding on to David Ward. I'd expect him to be in contact with you early next week.

Regards,

Stephen Griffiths
R&D Manager | Intermap Technologies Corp. | Calgary, Alberta, Canada
Tel. 1.403.266.0980 Ext 305 | Fax. 1.403.265.0499 | Cell 1.403.612.7300
sgriffiths@intermap.com | www.intermap.com

From: Fennelly, Benjamin T [mailto:ben.fennelly@atkinsglobal.com]
Sent: Friday, July 27, 2012 9:48 AM
To: Stephen Griffiths
Subject: RE: Big Hole River, MT

The survey was also collected in NAVD88.

Benjamin T. Fennelly, PE, CFM
Senior Engineer, Integrated Water Resources

ATKINS

3810 Valley Commons Drive, Suite 4, Bozeman, MT 59718 | Phone: +1 (406) 587 7275 Ext. 4111234| Fax: +1 (406) 587 7278
Email: ben.fennelly@atkinsglobal.com | Web: www.atkinsglobal.com/northamerica   www.atkinsglobal.com

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From: Stephen Griffiths [mailto:sgriffiths@intermap.com]
Sent: Friday, July 27, 2012 9:46 AM
To: Fennelly, Benjamin T
Subject: RE: Big Hole River, MT

Hi Ben,

Can you tell me the Vertical datum used for the survey data? We use NAVD88 for the NEXTMap data.

Thanks,

Stephen Griffiths
R&D Manager | Intermap Technologies Corp. | Calgary, Alberta, Canada
Tel. 1.403.266.0980 Ext 305 | Fax. 1.403.265.0499 | Cell 1.403.612.7300
sgriffiths@intermap.com | www.intermap.com

From: Fennelly, Benjamin T [mailto:ben.fennelly@atkinsglobal.com]
Sent: Thursday, July 26, 2012 5:28 PM
To: Stephen Griffiths
Cc: March, Dan; Story, Steve
Subject: Big Hole River, MT

Steven,

As I stated in my voicemail, I have attached a shapefile of the survey points that we have gathered along the river. Within the shapefile, I have added a few attributes stating the corresponding elevation of the grids we were sent (via Intermap) along with the difference between the survey elevation and the grids. The location that jumped out at me was the area covered by points FID 11 – 503 (of the attached shapefile). All of the other areas of the grids provide a reasonable approximation of the surveyed elevations.

Please let me know if you have any questions,

Ben

Benjamin T. Fennelly, PE, CFM
Senior Engineer, Integrated Water Resources

ATKINS

3810 Valley Commons Drive, Suite 4, Bozeman, MT 59718 | Phone: +1 (406) 587 7275 Ext. 4111234| Fax: +1 (406) 587 7278
Email: ben.fennelly@atkinsglobal.com | Web: www.atkinsglobal.com/northamerica www.atkinsglobal.com

Fennelly, Benjamin T

From: Story, Steve [sestory@mt.gov]
Sent: Tuesday, August 07, 2012 2:56 PM
To: March, Dan; Fennelly, Benjamin T
Subject: FW: Big Hole Information
Attachments: Montana_Survey_Point_InspectionFINAL.ppt

FYI

Stephen E. Story, PE, CFM
MT DNRC, Water Resources Division
406.444.6664

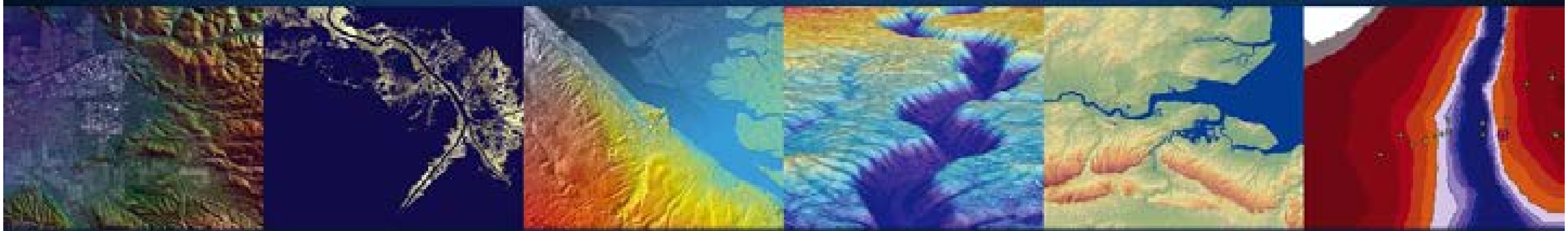
From: David Ward [mailto:dward@intermap.com]
Sent: Tuesday, August 07, 2012 2:18 PM
To: Story, Steve
Subject: Big Hole Information

Steve:

I would like to walk you through this when you have a few minutes today. We discovered that most of the major errors were where we had removed the bridge decks. For the data to by hydro enforced this is necessary. Take a look and we can talk.

Regards
Dave

INTERMAP



Montana Survey Point Inspection

July 27, 2012

www.intermap.com

Summary

- This presentation shows an inspection of the survey point comparison with Intermap's delivered DTM data in Big Hole River, Montana

- The statistical results show that the survey data points are within Intermap's product specification, even when obstructed and high slope points are included

- The visual inspection shows that most of the problematic points occur near zones where ancillary data are fused into the DTM and on bridge decks, as well as some roads and river embankments

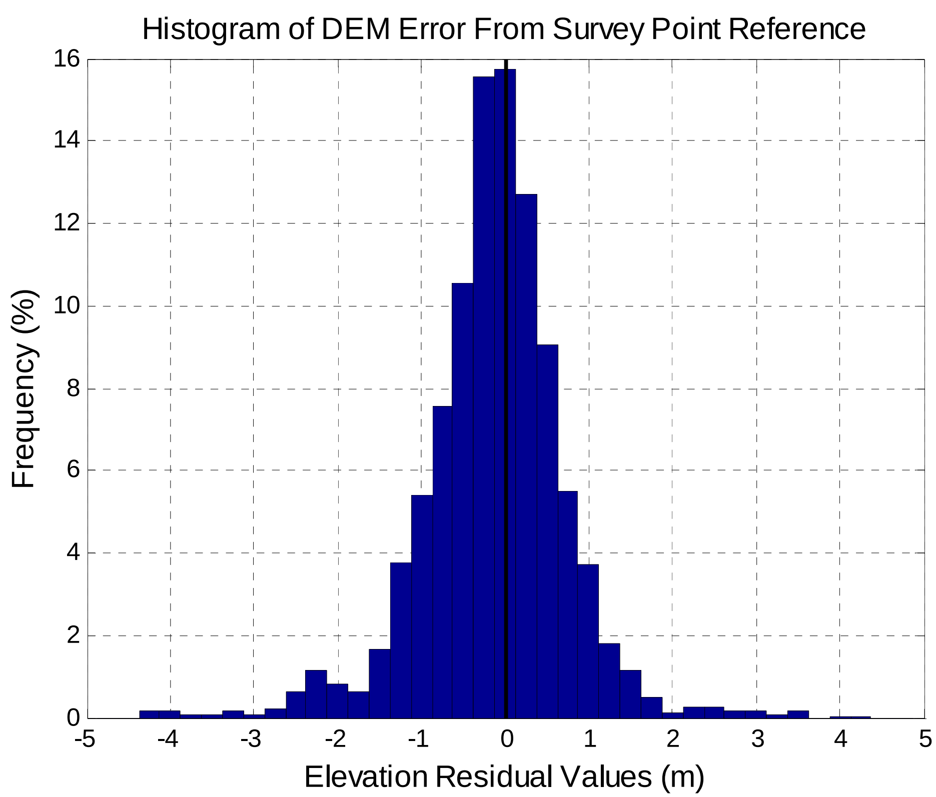
Overall Statistical Summary

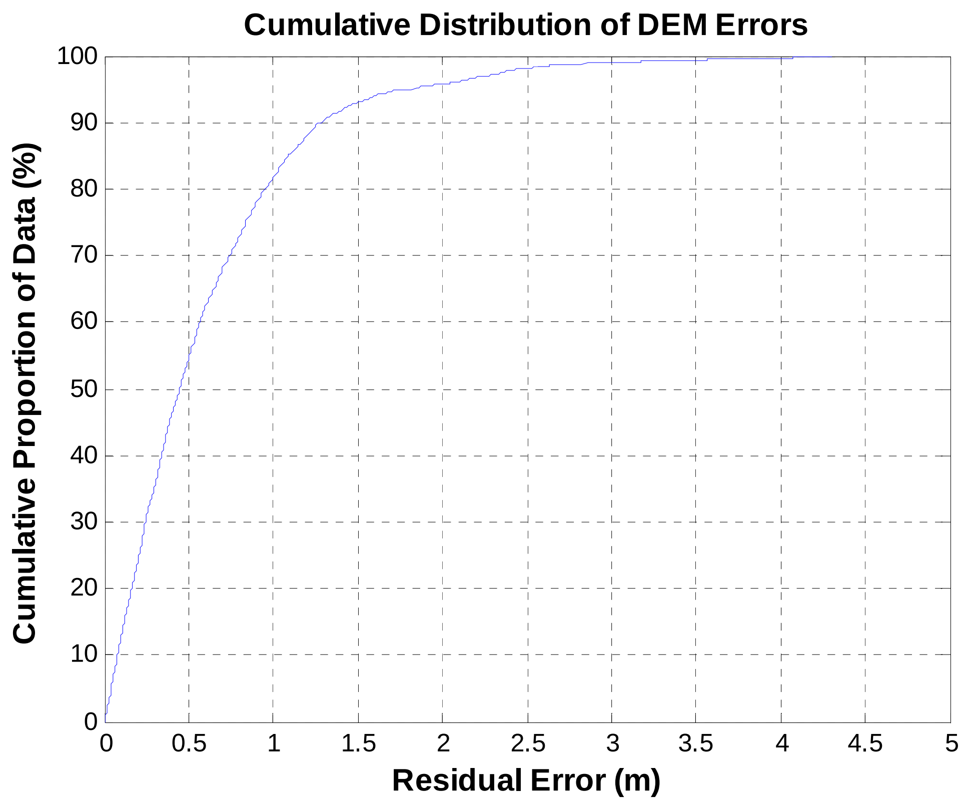
INTERMAP

Min = -4.30 m
Max = 4.30 m
Mean = -0.14 m
Std. Dev. = 0.86 m
RMSE = 0.87 m
LE90 = 1.29 m

The full set of survey points (including obstructed and high slope points) meets the Type II DTM specification for low-slope unobstructed terrain:

DTM Error < 1.0 m RMSE





Inspection of DTM Errors – SW Area

INTERMAP

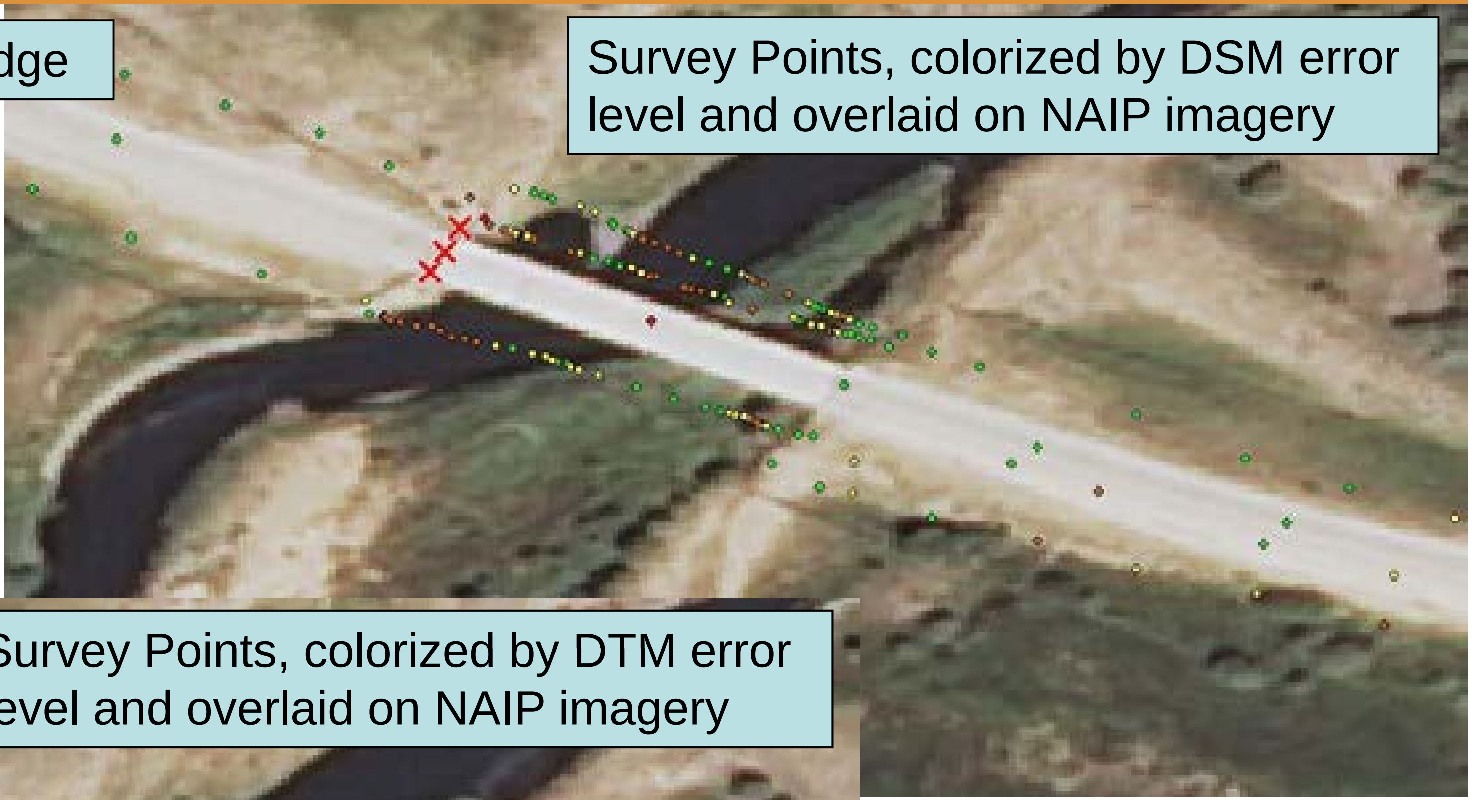
DTM Error Legend

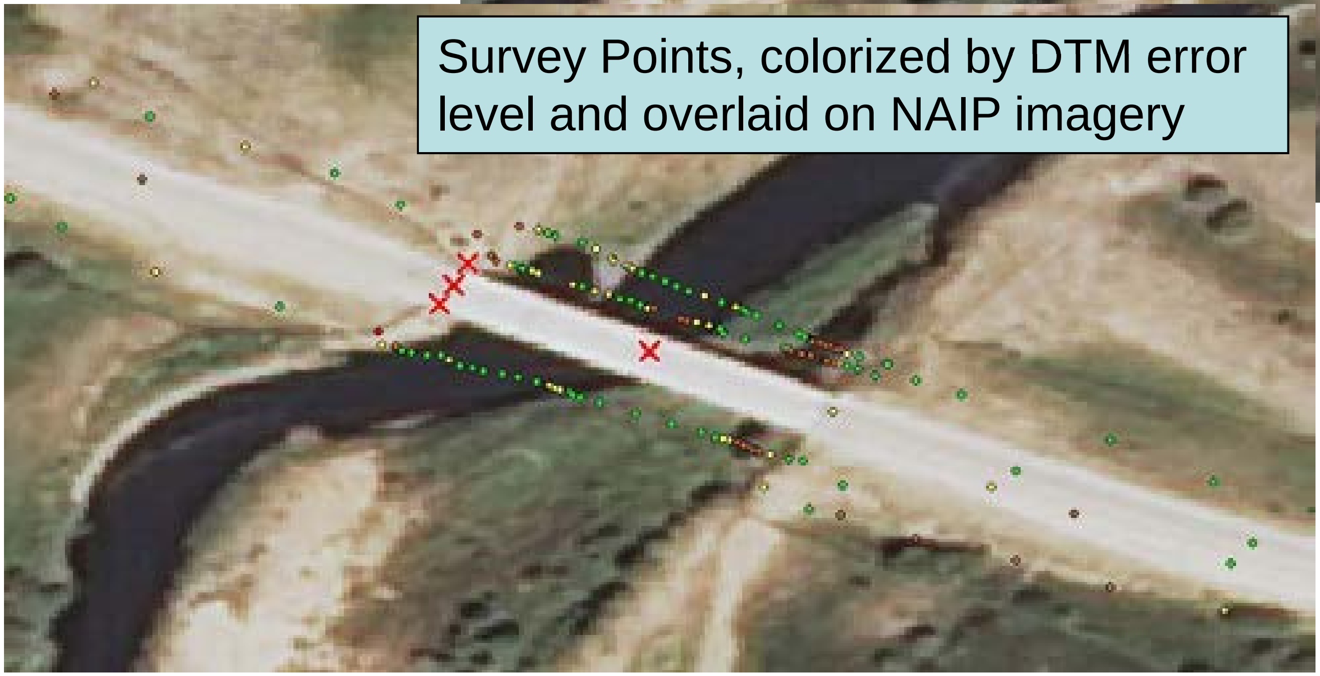
- Error < 50cm
- 50cm < Error < 1m
- 1m < Error < 2m
- 2m < Error < 3m
- X Error > 3m

Survey Points, colorized by DTM error level and overlaid on NAIP imagery

Inspection of DEM Errors – SW Area

Zoomed view of bridge





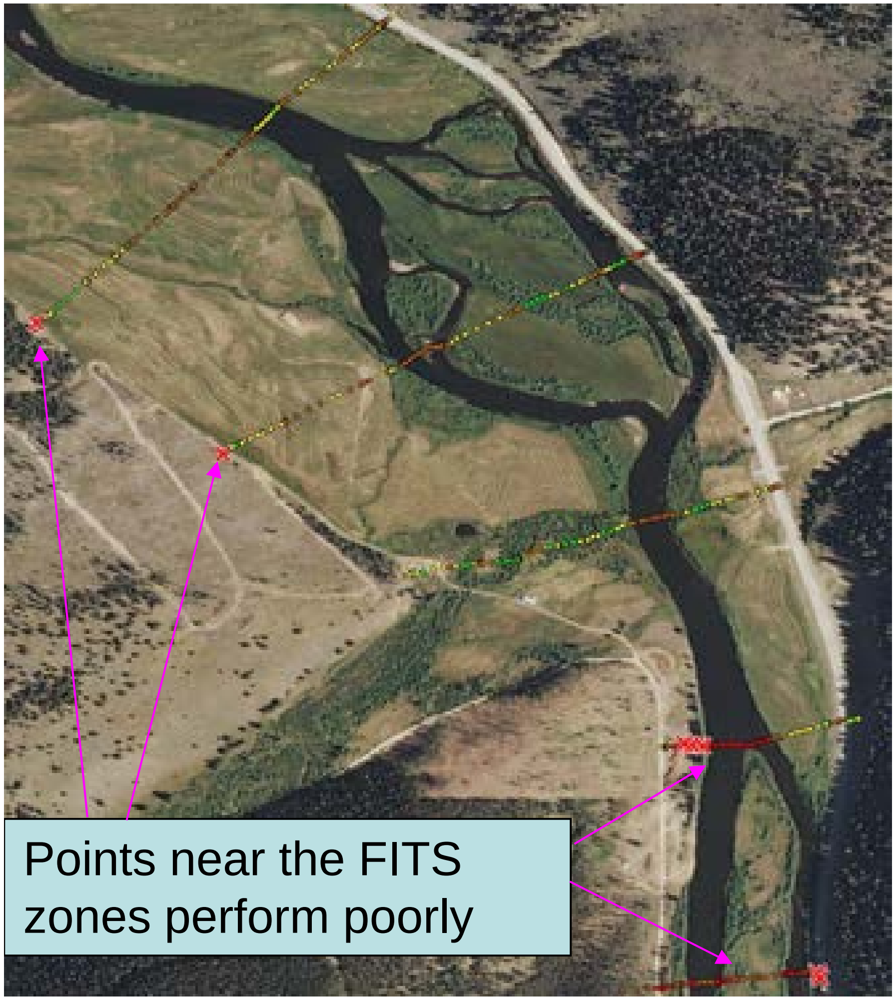
Inspection of DTM Errors – North Area

DTM Error Legend

- Error < 50cm
- 50cm < Error < 1m
- 1m < Error < 2m
- 2m < Error < 3m
- X Error > 3m

Edit Mask Legend

- Bald Terrain
- Lake
- River
- Built Terrain
- FITS



Survey Points, colorized by DTM error level and overlaid on NAIP imagery

Inspection of DTM Errors – SE Area

INTERMAP

DTM Error Legend

- Error < 50cm
- 50cm < Error < 1m
- 1m < Error < 2m
- 2m < Error < 3m
- X Error > 3m

Survey Points, colorized by DTM error level and overlaid on NAIP imagery

Poor results on bridge deck and embankments

Atkins
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